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Economic Benefit of Coal Utilization/Conversion at Air Force Bases: Screening Study

J. F. Thomas
F. P. Griffin
J. M. Young

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To meet the objectives of the Air Force Coal Utilization/Conversion Program, data was reviewed pertaining to oil- and gas-fired central heating plants at Air Force installations in the contiguous 48 states and Alaska. The objective of this report is to develop a list of the 15 to 20 sites best suited for coal use.

The economics of coal utilization favor heating plants with large capacity systems and high load factors. Heating plants were screened for annual fuel use, and those consuming an average of 30 MBtu/h were given further consideration. This initial list identified steam plants at 24 Air Force installations which met this fuel use criterion. (Continued)

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19. Abstract (continued)

Economic analysis of possible coal utilization projects was used as a tool to identify where coal potentially is the most and least attractive. Based on this economic analysis and consideration of fuel and electric use and prices, eight Air Force sites were eliminated from further consideration.

Oil- and gas-fired steam plants at 16 Air Force bases are recommended for further consideration for coal utilization projects. The information in this report will assist closer examination of steam plants to develop a priority order of sites considered for coal utilization projects.

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Air Force Coal Utilization Program

ECONOMIC BENEFIT OF COAL UTILIZATION/CONVERSION AT AIR FORCE BASES: SCREENING STUDY

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J. M. Young

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NOTICE *This document contains information of a preliminary nature. It is subject to revision or correction and therefore does not represent a final report.*

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LIST OF TABLES

LIST OF SYMBOLS, ABBREVIATIONS, AND ACRONYMS

AAC	Alaskan Air Command
AFA	Air Force Academy
AFB	Air Force Base
AFESC	Air Force Engineering and Service Center
AFLC	Air Force Logistics Command
AFRES	Air Force Reserve
AFSC	Air Force Station Command
ATC	Air Training Command
AU	Air University
baghse	baghouse
Bldg.	building
BLRS	boilers
Btu	British thermal unit
BBtu	billion Btu
C	coal
Ca	calcium
CAP	capital investment
cap fac	capacity factor
CERL	Construction Engineering Research Laboratory
COM	Air Force Major Command
CY	calendar year
DEIS	Defense Energy Information System
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
eff	efficiency
f	fixed cost
°F	degree Fahrenheit
FBC	fluidized bed combustion
FUEL	annual fuel cost
FY	fiscal year
G or Gas	natural gas
gal	gallon
h	hour
HHV	higher heating value
HTHW	high-temperature hot water
H_2O	water
inc.	including
kVA	kilovolt-ampere: one thousand volt-ampere
kWh	kilowatt-hour: one thousand watt-hour
K$	thousand dollars
lb	pound
LCC	life-cycle cost
LIM	limitation on fuel use data
MAC	Military Airlift Command
MFBI	Major Fuel Burning Installation
MBtu	megaBtu: one million Btu
MW	megawatt: one million watt
MWh	megawatt-hour: one million watt-hour
N	no secondary fuel

NG	natural gas
NO_x	nitrogen oxides
O&M	operating and maintenance
ORNL	Oak Ridge National Laboratory
P	propane
PR	current primary fuel
pres	present
psi	pounds per square inch
psig	pounds per square inch gauge
R.O.M.	run-of-mine
S	sulfur
SAC	Strategic Air Command
SE	current secondary fuel
SO_2	sulfur dioxide
SPCMD	Space Command
TAC	Tactical Air Command
UPWF	uniform present worth factor
v	variable cost
2	No. 2 oil (distillate oil)
4	No. 4 oil (distillate oil)
5	No. 5 oil (residual oil)
6	No. 6 oil (residual oil)
?	data are missing or suspect

EXECUTIVE SUMMARY

In support of the Air Force Coal Utilization/Conversion Program, ORNL has reviewed data pertaining to oil- and gas-fired central heating plants at Air Force installations in the contiguous 48 states and Alaska. The objective of this review is to develop a list of the 15 to 20 sites best suited for coal use.

The economics of coal utilization favor large-capacity systems and high load factors; facilities that are large fuel users are generally better candidates for coal use than those using less fuel. Heating plants were screened for annual fuel use, and those consuming an average of 30 MBtu/h were given further consideration. This initial list identified heating plants at 24 Air Force installations that met this fuel use criterion.

Economic analysis of possible coal utilization projects was used as a tool to identify where coal potentially is the most and least attractive. Based on this economic analysis and consideration of fuel and electric use and prices, eight Air Force sites were eliminated from further consideration.

Oil- and gas-fired heating plants at 16 Air Force bases are recommended for further consideration for coal utilization projects. The information in this report will assist closer examination of heat plants to develop a priority order of sites considered for coal utilization projects.

1. INTRODUCTION

Oak Ridge National Laboratory (ORNL) is supporting the Air Force Coal Utilization/Conversion Program by providing the Air Force Engineering and Services Center (AFESC) with a defensible plan to meet the provisions of the Defense Appropriations Act of 1986 (PL 99-190 Section 8110). This Act directs the Air Force to implement the rehabilitation and conversion of central heating plants (steam or hot water) to coal firing, where a cost benefit can be realized. This directive only applies to installations in the contiguous 48 states and Alaska.

Several essential tasks required to comply with the directive are to (1) identify the Air Force bases that have oil- and/or gas-fired central heating plants; (2) determine those heating plants that can be modified to burn coal and at the same time realize a cost benefit, and (3) categorize the selected heating plants according to their overall potential for coal use, therefore establishing a list of plants that will warrant further, detailed investigation. This report addresses these tasks.

1.1 RELATED WORK

A complementary study was previously completed by ORI, Inc. and C. H. Guernsey & Co,[1] that examined central heating plants at 34 selected Air Force bases. Leading candidate heating plants were identified for a few specific coal-conversion scenarios that fit two categories: (1) complete conversion of the existing heat systems to coal-firing by boiler conversion or replacement, or (2) building coal-fired cogeneration systems sized to meet peak electric loads. Only stoker coal-firing technology was considered in the report.

A separate but related study by ORNL examined the full range of available coal-burning technologies applicable to conversion of Air Force central heating plants.[2] The capital and operating costs for these technologies were estimated generically for typical heating plant installations. Understanding the costs, applicability, and performance of the coal-burning technologies is necessary for evaluating the heating plants considered in this study. The cost equations used in this study are presented and described in Ref. 2.

1.2 PURPOSE

The primary objectives of this study were to (1) examine and analyze the significant Air Force heating plants, (2) rank or categorize the selected central heating plants according to their estimated potential for coal utilization, and (3) identify the best 15 to 20 candidates for conversion to coal. The ORI, Inc. and C. H. Guernsey & Co. report had a similar objective, although the approach and emphasis were different. The results of the analysis and other information pertaining to the selected heating plants presented in this report, along with the results of the study by ORI, Inc./C. H. Guernsey & Co., will form a basis for choosing the "top candidate" heating plants for a subsequent study.

1.3 METHOD

Air Force facilities within the United States contain a large number of steam and hot water plants. Because there are numerous plants to be considered, simple methods of reducing the list of potential coal-using plants were employed at the onset of the study. As a start, oil- and gas-fired heating plants thought to be of significant size (>10 MBtu/h output) were identified. Size, in this context, is measured by system output capacity and/or annual fuel usage. Approximately 40 Air Force bases were identified as having one or more central heating facility with significant steam or hot water capacity, thus making them candidates for further consideration for coal conversion.

Coal firing is historically uneconomical for the smaller-sized industrial and commercial heating systems. It is more attractive for larger systems, especially those with high load factors. The economic benefit of coal over oil and gas depends on significant savings in fuel costs; therefore, fuel consumption is a very important economic parameter to be studied. A threshold value for annual fuel use was identified as a cut-off point for eliminating heating plants from the study. Heating systems using less fuel than this cut-off value were eliminated from consideration. For such sites, any potential fuel cost savings would not be large enough to justify the operating and maintenance (O&M) costs or the capital investment for coal equipment. These initial screening criteria were aimed at reducing the list of heating plants to realistic candidates.

The heating plants chosen by the initial screening were examined more closely, and a simple economic analysis of coal utilization was performed for each base. After considering the results of the economic analysis, heating plants were then ranked. Several sites were eliminated from consideration based on this economic analysis and a number of other factors, such as the potential for cogeneration.

Available information on Air Force central heating plants was collected and organized in order to examine conversion to coal firing. Emphasis was placed on determining the heat loads, existing boiler design and condition, and fuel costs for each heating plant considered. In a parallel effort, a data base concerning many major Air Force installation heating plants was developed that used the information collected for this effort. This data base has been used as an information source for certain portions of this study.

1.4 LIMITATIONS

The lack of information presents some limitations to this study. Missing information includes the price and properties of coal available to each Air Force base and the local air quality constraints. Furthermore, some site-specific information may not have been thoroughly considered, such as aesthetics, lack of space at the boiler plant, and the precise design and condition of the existing equipment. A subsequent effort will fill in this missing information and provide a more detailed evaluation of selected heating plants.

Another consideration is the future fluctuation of fuel prices, which will affect the economics of coal projects. Future re-evaluation of certain heating plants will be necessary as fuel prices change.

Despite the lack of some information, this report serves as an effective screening study to identify Air Force central heating plants that have the most potential for coal use. Information presented will serve as a basis for future detailed studies of individual heating systems.

2. INITIAL SCREENING OF HEATING PLANTS

For the first step in the screening study, information that would aid in assessing the potential for coal utilization/conversion was gathered for each Air Force heating plant. Using this information, a list of oil- and gas-fired Air Force heating plants of significant size was developed. From this list, those systems having the most potential for conversion to coal could be selected.

2.1 SOURCES OF INFORMATION

2.1.1 ORI, Inc. and C. H. Guernsey & Co. Report

A 1988 report by ORI, Inc. and C. H. Guernsey & Co.[1] provided much useful information needed to evaluate the coal utilization options at 34 Air Force base heating plants. In this report 34 Air Force bases were examined by using questionnaires, phone contacts, and personal visits to collect information needed to evaluate coal utilization options at heating plants (including cogeneration of steam and electricity). Other sources of information, such as previous Air Force assessments, were also used to supplement the efforts to obtain information. This study was particularly helpful because of the current oil, gas, and electricity prices obtained, along with other up-to-date information.

2.1.2 Defense Energy Information System Data

Monthly fuel and electric use and their costs at Air Force installations are collected and logged into what is known as the Defense Energy Information System (DEIS). The data apply to an installation as a whole and are separated into two categories: military family housing and industrial energy use. The data are also separated by type of fuel. Information concerning fuel use specific to a given heating plant is not included; therefore, the fuel consumption data have limited use for this study. However, at some sites it is known that certain fuels, such as coal or residual oil, are only burned in boilers. In some cases, the fuel-use data can directly indicate boiler plant load. This normally does not apply to gas and light oil consumption, which is very often used for a variety of applications other than boiler firing. The monthly electric usage and costs for each installation are also useful for evaluating cogeneration projects.

2.1.3 Air Force Heat Plant Studies

Recent Air Force internal reports[3-5] contain information on steam and high-temperature hot water (HTHW) loads; fuel use; and electrical demand for many of the Air Force Logistics Command (AFLC), Military Airlift Command (MAC), and Strategic Air Command (SAC) heating plants. These studies included most of the Air Force sites that are the largest consumers of oil and gas, and each study examined energy consumption in one or more years during 1984 through 1986. These studies were done at the request of AFESC.

2.1.4 Hartford Data Base

The Hartford Boiler Insurance Co. developed a data base that identified the location, size, fuel type, pressure rating, and other useful information pertaining to Air Force boilers. The Construction Engineering Research Laboratory (CERL) of the Army Corps of Engineers maintains this data base for the Air Force. These data were particularly useful in verifying changes in the status of certain boilers, such as scrapping, replacing, mothballing, or adding new units.

2.1.5 MFBI Survey

A significant amount of information concerning important Air Force heat plants was gathered from a 1980 inventory of Air Force heating system boilers having an output capacity >10 MBtu/h. This survey was part of the Federal Facilities Power Plant and Major Fuel Burning Installation Survey (MFBI Survey) requested by the U.S. Department of Energy (DOE) under the authority of the Power Plant and Industrial Fuel Use Act of 1978. A great deal of information included in the MFBI Survey was potentially useful in analyzing the central heating plants. However, the survey only covered the time period from 1978 to 1979, thus making the information somewhat outdated. It was, therefore, used carefully, and mainly as background information.

2.2 INITIAL LIST OF HEATING PLANTS

The first step toward screening the heating plants was to develop a list of plants that had the potential to be converted to coal. This list included all non-coal-burning Air Force heating plants known to have boilers with a fuel input rating >10 MBtu/h. Because small coal-fired systems are inherently uneconomical, heating plants known to have no boilers >10 MBtu/h were eliminated from consideration, unless the plant aggregate boiler capacity was ≥30 MBtu/h. In addition, a data base on many of these Air Force central heating plants was developed in support of the analysis efforts.

Information used to compile both the list of heating plants and the data base came from the sources identified in Sect. 2.1. Note that definitive information was not obtained for every Air Force installation within the contiguous 48 states and Alaska, but it is believed that no important heating plants were overlooked.

The initial list consisted of over 70 steam or hot water systems. It was apparent that this list needed to be narrowed to a more manageable number. The initial heating plants considered are listed in Tables 1 and 2.

2.3 ELIMINATION OF SMALL FUEL-CONSUMING PLANTS

The costs of oil-, gas-, and coal-fired boiler/hot water systems were reviewed in a separate task.[2] These costs, combined with information on various heating plants, allowed for some preliminary economic analysis to be performed on typical Air Force central heating plants. It was determined that if the heating plant had a fuel usage that averaged ≤30 MBtu/h, coal would not be economical based on any reasonable scenario.

The next logical step was to eliminate all heating plants from consideration that did not meet these criteria. The actual criterion used

Table 1. Heating plants meeting fuel use criteria

Base	COM[a]	Building No.	Number of BLRS[a]	Type of fuel[b] PR[a]	Type of fuel[b] SE[a]	Plant capacity (MBtu/h)	1978 Fuel use (BBtu)	LIM[a]	1979 Fuel use (BBtu)	LIM[a]	1985 Fuel use (BBtu)	URI survey (BBtu)
Elmendorf	AAC	22-004	6	G	2	900	2673		2694			2616
USAF Academy	AFA	2560	4	G	5	380	800	?	800	?		562
Hill	AFLC	260	8	G	2	258	1331		1087		1074	
Hill	AFLC	825	3	G	2	150					300	
Kelly	AFLC	376	5	G	2	259	597		570		540	504
McClellan	AFLC	367	2	G	5	100	129	G	170	G	340	
Robins	AFLC	177	5	G	2	358	948		903		865	872
Tinker	AFLC	3001	3	G	2	291	1262		1411			
Tinker	AFLC	208	4	G	2	164	671		647			
Arnold	AFSC	1411	4	G	2	240	599		589			642
Hanscom	AFSC	1201	4	6	G	203	739		751			856
Keesler	ATC	409	5	G	2	84						2300
Lowry	ATC	361	4	G	2	232	222		269			199
Maxwell	AU	1410	5	G	5	110	358		308			411
Andrews	MAC	1515/1732	8	6	N	295	527		546			557
Charleston	MAC	431	4	6	N	201	276		229		175	160
Dover	MAC	617	4	6	N	200	511		444		407	407
McChord	MAC	734	3	G	2	86	326		361		344	325
McGuire	MAC	2101	6	G	2	262	811		801		488	809
Scott	MAC	45	4	G	6	252	493		495		347	436
Grand Forks	SAC	423	5	6	P	159	548		611		555[c]	480[c]
Minot	SAC	413	6	G	6	167	584		644			463
Pease	SAC	124	2	G	6	220	433	6	337	6		370
Plattsburgh	SAC	2658	6	6	N	300	848		801			825
Whiteman	SAC	140	3	G	6	106	216		311			312
Wurtsmith	SAC	305	4	6	N	112	319		329			319

[a]COM — Air Force Major Command
BLRS — boilers
PR — current primary fuel
SE — current secondary fuel
LIM — limitation on fuel use data; G — only gas use, 6 — only residual oil use
? — data are missing or suspect

[b]Fuels: 6 — No. 6 oil (residual oil); 5 — No. 5 oil (residual oil); 2 — No. 2 oil (distillate oil); N — no secondary fuel; G — natural gas; P — propane.

[c]An electric boiler system is currently in use. An estimate of fossil fuel that would otherwise be consumed was calculated assuming a 75% overall output heat/fuel efficiency.

Table 2. Heating plants not meeting fuel use criteria

Base	COM[a]	Building no.	Number of BLRS[a]	Type of fuel[b] PR[a]	Type of fuel[b] SE[a]	Plant capacity (MBtu/h)	1978 Fuel use (BBtu)	LIM[a]	1979 Fuel use (BBtu)	LIM[a]	1985 Fuel use (BBtu)	ORI survey (BBtu)
USAF Academy	AFA	8026	2	G	5	60						38
Hill	AFLC	1286	3	G	2	113					190	
Hill	AFLC	1310	4	G	2	48						
Hill	AFLC	519	5	G	2	42						
Hill	AFLC	1624	2	G	2	25	3		5		12	
Hill	AFLC	1904	1	G	2	21	35		31		40	
Hill	AFLC	1205		G	2	17						
Hill	AFLC	1703		G	2	18						
Hill	AFLC	2025	3	G	2	18						
Hill	AFLC	2104		G	2	12						
Hill	AFLC	2203		G	2	12						
McClellan	AFLC	656	3	G	5	56	124	G	133	G	192	
McClellan	AFLC	486	2	G	5	27	63	G	88	G	51	
Robins	AFLC	644	4	G	2	93	214		218		174	134
Robins	AFLC	54	1	2	N	21	0		8		3	
Tinker	AFLC	5802	2	G	2	28	55		73			
Dobbins	AFRES	728	4	G	5	35	0		0			
Willow Grove	AFRES	212	2	6	N	34	43		37			
Arnold	AFSC	535 B	1	G	2	57	54		40			
Brooks	AFSC	165	4	G	2	132						103
Patrick	AFSC	55055	3	5	N	45	143		116			
Chanute	ATC	988	2	5	N	37	37		37			30
Keesler	ATC	4101	3	G	2	51						?300
Williams	ATC	237	2	G	2	29	0	P	24	P		
Andrews	MAC	3409	5	6	2	77	195		184		135	
Bolling	MAC	18	3	2	N	75	130		71			177
Fairchild	MAC	9005	2	G	6	31	40		41			
Kirtland	MAC	1013	4	G	2	64	165		161			
Norton	MAC	716	4	G	2	121	200		229			157
Norton	MAC	754	4	G	N	101	128		95			74
Scott	MAC	869	2	6	2	30	23		33			22
Scott	MAC	3191	2	6	2	22	9		10			8
Scott	MAC	3670	2	6	2	14	13		15			16
Ellsworth	SAC	1107	3	G	2	20	10		16			
Ellsworth	SAC	1211	3	G	2	20	14		25			
Ellsworth	SAC	5902	4	G	2	57	20		31			
Ellsworth	SAC	7504	3?	G	2	89	61		63			
Minot	SAC	Hospital	4	G	2	34	28		31			
Offutt	SAC	304	2	G	2	24	80		42			
Offutt	SAC	308	3	G	2	?	?		?			
Offutt	SAC	500	3	G	2	?	180		130			
Offutt	SAC	4000	2	G	2	?	32		33			
Langley	TAC	655	3	G	4	104	233		219			136
Langley	TAC	753	2	G	4	72	69		87			103
Langley	TAC	80	3	G	4	53	18		28			74
Pope	TAC	251	2	G	2	3						4
Pope	TAC	289	2	G	2	7						13
Pope	TAC	350	3	G	2	10						21
Seymour Johnson	TAC	4503	3	5	N	30	50		60			59
Seymour Johnson	TAC	2700	3	5	N	79	171		178			236
Seymour Johnson	TAC	5000	3	5	N	22						67

[a]COM — Air Force Major Command
BLRS — boilers
PR — current primary fuel
SE — current secondary fuel
LIM — limitation on fuel use data; G — only gas use, P — only propane use
? — data are missing or suspect

[b]Fuels: 6 — No. 6 oil (residual oil); 5 — No. 5 oil (residual oil); 4 — No. 4 oil (distillate oil);
2 — No. 2 oil (distillate oil); N — no secondary fuel; G — natural gas; P — propane.

to eliminate small heating plants was fuel consumption of <260 BBtu/year, which is equivalent to a year-round average of 30 MBtu/h. Table 1 lists the heating plants that meet the size criteria along with information pertinent to choosing these plants. Any heating plant that was reported to have fuel use in excess of 260 BBtu/year for some year was included in Table 1, even if the fuel use is reported as lower in other years [e.g., Lowry Air Force Base (AFB) and Charleston AFB]. Note that Andrews AFB has two central heat plants feeding a common distribution system, and these two plants are treated as a single heat plant.

Twenty-six heating plants at 24 Air Force sites are identified in Table 1 and will be examined further in this report. The heating plants that were too small for consideration and those that are already coal-fired are listed in Tables 2 and 3, respectively.

Table 3. Heating plants burning coal

Base	COM[a]	Building No.	Number of BLRS[a]	Type of fuel[b]		Plant capacity (MBtu/h)	1978 Fuel use (BBtu)	1979 Fuel use (BBtu)	1985 Fuel use (BBtu)
				PR[a]	SE[a]				
Eielson	AAC	6203	6	C	N	720	2228	2052	1613
Wright Patterson	AFLC	66[c]	7	C	N	506	1062	942	c
Wright Patterson	AFLC	170[c]	2	C	N	240	809	686	c
Wright Patterson	AFLC	770	5	C	N	160	323	337	
Wright Patterson	AFLC	1240	5	C	N	130	399	305	
Wright Patterson	AFLC	271[c]	3	C	N	108	205	250	c
Wright Patterson	AFLC	Total for plants 770 and 1240							2340
Chanute	ATC	46	5	C	N	280	1152	1063	740
Fairchild	SAC	2175	4	G	2	470	578	607	N/A
Fairchild	SAC	2175	4	C	G	470	N/A[a]	N/A	
Griffiss	SAC	117[c]	4	6	N	418	912	874	c
Griffiss	SAC	29	4	C		360	N/A	N/A	672
F E Warren	SAC	6500	3	C	N	165			216
Grissom	SAC	223	5	C	6	197	565	489	504
K I Sawyer	SAC	521	5	C	6	152	553	564	305
Loring	SAC	7310	6	C	2	378	854	850	600
Malmstrom	SAC	140[c]	3	G	2	40	87	85	c
Malmstrom	SAC	821	3	C		255	N/A	N/A	288
Clear	SPCMD	111	3	C		338	1500	1600	1320
MT Home	TAC	132	4	C					322

[a]COM – Air Force Major Command
BLRS – boilers
PR – current primary fuel
SE – current secondary fuel
N/A – not applicable

[b]Fuels: 6 – No. 6 oil (residual oil); 2 – No. 2 oil (distillate oil); C – coal; G – natural gas; N – no secondary fuel.

[c]Heating plant no longer in service.

3. LIFE-CYCLE COST ANALYSIS OF SELECTED HEATING PLANTS

Further examination of the 26 heating plants identified in Sect. 2 was necessary to gain a better understanding of the potential for coal utilization at each site. To accomplish this, some type of relatively simple economic analysis was needed to compare coal use with continued oil/gas firing. Some difficulties in this task were encountered because of missing information, fluctuating fuel prices, and the large number of possible project scenarios that could be considered for any heating plant. These issues are addressed in this section.

3.1 CHOICES FOR PROJECT SCENARIOS

Numerous coal utilization projects can be considered for a given site. Three basic project categories can be explored: (1) installing coal firing to meet base-load heating requirements and using other fuels to meet peak loads, (2) converting a plant to 100% coal-firing capability, and (3) cogenerating heat and electricity. A discussion of these three categories follows.

In the ORI, Inc./C. H. Guernsey & Co. study,[1] all the projects considered for evaluation included 100% coal-firing capability for the heat plant (with oil/gas as a secondary fuel). In some cases this may be the option required by the Air Force, but it is not often the most economical option. Many industrial and military steam/HTHW plants use coal-fired boilers for base-load operation (a level of heating load often required) and use oil and gas boilers for load following and peak demand. This type of arrangement is used mainly to minimize the overall cost of steam/HTHW.

3.1.1 Coal Firing to Meet Heating Base Load

Coal firing can be used to meet some level of base load for steam or HTHW demand. This is achieved by a combination of coal-fired boilers and oil-/gas-fired boilers. Relatively constant heating loads can be met by coal-fired equipment, but meeting high heating demands and following load changes can be done with gas/oil units. The amount of capital-intensive, coal-fired equipment is minimized, and the coal systems have a high use factor. Much of the fuel burned at the facility will be coal, but there is still dependence on gas/oil during high steam/HTHW demand periods.

The amount of coal-fired steam/HTHW capacity and oil-/gas-fired capacity is usually determined by economics. This type of central heating plant is common in industry and is used at some military sites.

3.1.2 Coal Firing for All Heat Generation

An entire central heating plant can be converted to coal firing with oil or gas as a backup fuel. The major advantage is that there is no significant dependence on oil or gas availability. All the projects evaluated in the ORI, Inc./C. H. Guernsey & Co. study included 100% coal-firing capability for the heating plant (with oil/gas as a secondary fuel). This may be preferable for various reasons, but it would not be the most economical option. Coal-fired boilers are capital intensive and cost more to maintain than oil/gas units. In general, the average load factors for the coal-firing equipment would be low, and such conversion projects would be costly. No economical projects of this type were identified in the ORI, Inc./C. H. Guernsey & Co. report.

3.1.3 Cogeneration of Electricity and Steam

Examination of coal-fired cogeneration options is more complicated than simply converting steaming capacity to coal. The choices when sizing a cogeneration facility include whether to meet the peak steam and/or peak electric demand, or to meet some base load of steam and electricity. If excess electricity is to be generated and sold, a number of regulatory and pricing considerations must be examined.

Many AFBs do not have room for a large cogeneration facility. Most of the existing heating plants are designed for low-pressure steam or HTHW. To convert to cogeneration would require replacing such boilers with high-pressure systems. Cogeneration projects will only be economically viable at Air Force facilities that use significant amounts of relatively costly electricity.

3.1.4 Choosing a Scenario

It is not worthwhile to perform an economic analysis of the heat plants listed in Table 1 for all three project scenarios identified in the preceding subsections. Instead, one type of scenario was chosen for the economic analysis; the results will then be examined and a decision made as to how to proceeded with the study. The major goal was to reduce the number of heating plants under consideration from 26 to 15 to 20.

The cogeneration project scenario is the most difficult to analyze because of the added complexity of electrical generation equipment costs and simulating electricity purchase and sales prices. It is unlikely that an analysis of complete conversion of the heat systems to coal firing will reveal any projects that show a cost savings. Complete conversion of heat plants to coal firing and a single type of cogeneration project (meeting peak electric load) have been already considered to an extent in the ORI, Inc./C. H. Guernsey & Co. study.[1] The remaining type of project to be considered is conversion of a portion of the existing heat capacity to coal firing. This latter type of coal utilization scenario appears to be the most meaningful scenario to pursue for this study.

3.2 COMPUTER PROGRAM FOR HEATING PLANT COST ESTIMATING

In a previous study by ORNL for the Air Force,[2] coal combustion technologies found to be applicable to Air Force central heating plants were reviewed and evaluated. As a part of that previous work, operating and maintenance (O&M) and capital cost equations were developed for the many coal technology options that could be employed at a heating plant. O&M cost equations for firing gas or oil at a central heating plant were also developed for comparison. A computer model, based on these cost equations, was developed to estimate heating plant costs for each of 13 different coal technology options and for gas and oil firing. The costs generated for the coal technology options can be compared with each other and with the costs of continued firing of gas or oil. A much more detailed discussion of the development of the heating plant cost estimating equations can be found in a report[2] prepared for AFESC entitled "Coal Burning Technologies Applicable to Air Force Central Heating Plants."

The 13 coal technologies included in the cost estimating model are divided into the following two categories:

Refit Technologies	Replacement Boilers
Micronized coal firing	Packaged shell stoker
Slagging pulverized coal burner	Packaged shell FBC
Modular FBC* add-on unit	Field erected stoker
Return to stoker firing	Field erected FBC
Coal/water slurry	Pulverized coal boiler
Coal/oil slurry	Circulating FBC
Low-Btu gasifier	

The refit technologies incorporate the existing boiler(s) and much of the peripheral equipment. Often, various modifications to the boiler may be required. In a micronized coal system, the coal is pulverized to a size that is much smaller than ordinary pulverized coal and is burned directly in the existing boiler. In a slagging system, pulverized coal is burned in a small, high-temperature cyclone burner that is connected to the existing boiler. In a modular FBC system, part of the steam is generated in an add-on, bubbling FBC unit, and the existing boiler is used as a waste heat recovery unit. The return to the stoker firing option can only be considered if the existing boiler were originally designed for stoker coal combustion. In slurry systems, the coal/water and coal/oil mixtures are burned directly in the existing boiler. In a gasifier system, stoker coal is gasified with air in an add-on unit and the hot, low-Btu gas is burned in the existing boiler.

The replacement boiler options involve reusing the existing water treatment system, steam or hot water distribution system, and other equipment peripheral to the boiler. The existing boilers are removed, decommissioned, or put on standby. Both packaged and field-erected

*FBC = fluidized bed combustion.

units have been examined for the stoker and bubbling FBC systems. The packaged units are factory-built, shell (fire-tube) boilers that are small enough to be shipped by rail. The field-erected units are larger, water-tube boilers. The pulverized coal-fired and circulating FBC boilers considered are field-erected, water-tube boilers.

Pollution control technology costs were considered to a limited extent. All 13 coal technologies are assumed to require baghouses to meet the particulate emission regulations. Particulate control beyond cyclone-type devices is required virtually everywhere in the United States, and baghouses are judged to be the most cost effective and have the most appropriate technology. NO_x emissions are assumed to be controlled with conventional combustion control systems for all coal technologies. Control of SO_2 was assumed to be accomplished by choosing the appropriate coal.

The computer model consists of two corresponding spreadsheets for each of the 13 coal technologies, one for estimating the capital investment and another for estimating O&M costs. Each spreadsheet calculates an itemized cost table, such as the examples shown in Tables 4 and 5. The purpose of using this itemized-cost table format is to generate very consistent and comparable cost estimates for each technology considered. Any calculated project costs can easily be examined in detail. The personal computer software package used to develop the costing program is Framework II™, by Ashton-Tate.

3.3 METHOD OF ECONOMIC ANALYSIS

The goal of applying an economic analysis to the selected heating plants is to establish an initial ranking indicative of the potential for economic coal utilization. This ranking can then be used along with other information to reduce the list of heating plants in Table 1 from 26 to 15 to 20. The project scenario chosen for the analysis was the conversion of base-load capacity of each heating plant to coal firing. Other types of project scenarios can be explored later, if necessary. Note that the economic analysis is an exercise for screening heat plants, and other information and considerations must be taken into account before eliminating any heat plants from consideration.

Table 4. Example computer-generated capital investment cost spreadsheet for micronized coal firing

Technology: MICRONIZED COAL BURNER - REFIT TO EXISTING BOILER 20-200 MBTU/H	Size (MBtu/h) Output heat = 72.0 No. of units = 1 Output/unit = 72.0

Multiple unit multiplier = 1

ITEM	SCALING FACTOR	COST (k$)
Site work & foundations	.50	24
Boiler modifications	.50	12
Soot blowers	.60	0
Micronized combustor system	.52	176
Boiler house modification	.50	24
Fuel handling & storage	.40	781
No bottom ash system		0
Ash handling	.40	298
Electrical	.80	100
Baghouse	.80	520
Subtotal		1935
Indirects (30%)		581
Contingency (20%)		503
Total for each unit		3019
Grand total		3019

Table 5. Example computer-generated O&M cost spreadsheet for micronized coal firing

Technology: MICRONIZED COAL BURNER REFIT TO EXISTING BOILER SIZE 10-200 MBTU/H

Total heat output (MBtu/h)	= 72.0	COAL, LIMESTONE, ASH	
Number of units converted	= 1	Ash fraction	= .10
Unit output (MBtu/h)	= 72.0	S fraction	= .015
Fuel to steam/HTHW eff.	= .80	HHV (Btu/lb)	= 12000
Capacity factor	= .72	Ton coal/year	= 23652
Ash disposal price ($/ton)	= 10.00	Ca/S ratio	= .00
Electric price (cents/kWh)	= 4.50	Inert fraction	= .05
Labor rate (k$/year)	= 35.00	Ton sorbent/year	= .0
Limestone price ($/ton)	= 20.00	Waste/sorbent	= .858
		Ton ash/year	= 2365

CATEGORY	SCALING FACTOR	COST (k$)
Direct manpower (f)	.18	557.9
Repair labor & materials (f)	.36	374.3
Electricity (f)	1.00	36.2
Electricity inc. baghse (v)	1.00	74.1
Baghouse (f)	.36	29.8
Limestone (v)	1.00	.0
Ash disposal (v)	1.00	23.7
Nonfuel O&M total		1095.9

3.3.1 Project Assumptions

The type of conversion project being considered involves using coal for base-load heat production as opposed to converting the entire heating plant to coal firing. In practical terms, this involves converting or replacing one to three existing boilers at the heating plants being examined. The decision of how much boiler capacity to replace or refit will affect the economic results. Care was taken to find the project size to give the best economic results.

In actual practice, replacement boilers do not need to have the same output capacity as the boilers they replace. When an existing boiler is refitted for coal firing, the output capacity may be altered (usually lowered) for technical reasons. For the purposes of this study, boiler capacities were usually assumed to be the same as those of an existing boiler. Project-size optimization tests were carried out (but not presented in this report) to ensure the results presented in this report approximate the optimum project size.

The Air Force sites under consideration fall under a broad spectrum of air quality regulations. These regulations are not fully reflected in this report but will play an important role in future analyses. For this study it was assumed that baghouses were required for particulate control in every case. Emission requirements for SO_2 and NO_x are assumed to be met by using low-sulfur coal and good combustion control. This assumption will be optimistic (toward coal use) in some cases.

3.3.2 Economic Assumptions

The economic and cost parameters used in this study are listed in Table 6. The economic ground rules represent an Air Force plant built under the Military Construction Program. Other major economic parameters include a 30-year economic life and a 10% discount rate. No fuel cost escalations are considered, and general inflation is assumed to be negligible.

Because the prices of locally obtainable coal are not known for the sites considered, somewhat optimistic (low) coal prices were assumed. A single coal price for stoker coal and a single price for run-of-mine

Table 6. Economic and cost parameters for life-cycle cost calculations

Economic assumptions:

- Project is under the Military Construction Program
- Discount rate is 10%
- Economic life is 30 years
- Uniform present worth factor applied to fuel and O&M costs is 9.427
- No salvage value
- No property tax or insurance
- No real escalation of fuel and O&M costs
- Inflation effects are negligible
- All capital is invested at the project start

Major cost assumptions:

Cost of stoker coal	\$1.75/MBtu
Cost of run-of-mine coal	\$1.50/MBtu
Cost of coal/water slurry	\$3.00/MBtu
Cost of coal/oil slurry	\$3.50/MBtu
Cost of No. 6 residual oil	\$3.67/MBtu (\$0.55/gal)
Cost of No. 2 distillate oil	\$4.71/MBtu (\$0.65/gal)
Labor rate	\$35,000/man-year

coal was used for all heating plants examined. Costs for coal slurries were estimated from literature studies[6] and contact with suppliers. The slurry costs do not represent actual current prices, but rather are the expected prices if large quantities of slurry were produced within a few hundred miles of the heat plant.

Costs for distillate and residual oil were assumed to be \$0.65/gal and \$0.55/gal, respectively. These were the Department of Defense (DOD) Stock Fund prices during FY 1988. Current natural gas prices being paid by the Air Force installations were obtained when applicable.

A constant labor rate of \$35,000/man-year for boiler operators and maintenance personnel was assumed. This cost includes all benefits, overhead, and supervision.

Although several of the economic parameters and cost assumptions may be somewhat inaccurate in some cases, it should be remembered that the purpose of the analysis is to screen the heating plants for those that are potentially attractive for coal use. Other factors will be considered beyond the result of the economic screening analysis before a heat plant is dropped from consideration.

3.3.3 Calculating Life-Cycle Cost and Benefit/Cost Ratio

The life-cycle cost (LCC) of a project is calculated by the equation

$$LCC = CAP + [(Fuel + O\&M) \times UPWF] ,$$

where

CAP = capital investment,

FUEL = annual fuel cost,

O&M = annual operating and maintenance cost,

UPWF = uniform present worth factor.

The assumption is made that the series of annual fuel and annual O&M costs will remain uniform (in constant dollars) over the life of the project. For a 30-year life and 10% discount rate, the uniform present worth factor is 9.427.[7,8]

To examine the value of coal utilization at a given site, the LCC of the proposed project must be compared with the LCC for continued use of a corresponding portion of the existing system. For example, if one boiler is to be converted to coal firing, the LCC of that project is compared with the LCC for continuing to use that same boiler firing the present fuel (oil or gas). The LCC values are not for the entire heating plant but only for that portion of the plant under consideration. The LCC for the remainder of the plant is assumed unchanged.

A number of values could be used to measure the economic advantage (or disadvantage) of the coal utilization project, including percent savings-to-investment ratio, total LCC savings, or an LCC ratio. For this report, the ratio of the LCC for continued oil/gas firing to the LCC of the coal utilization project was chosen. This ratio is referred to here as the benefit/cost ratio. A value >1 indicated a cost benefit from the coal project and <1 indicated money is lost by coal utilization.

The benefit/cost ratio is judged to be a good indicator of the probability that a cost savings can be realized for a given project and therefore was chosen as a means to rank the results. Future decisions concerning the size and type of project to be implemented at a given site would also be based on total estimated LCC savings and possibly other parameters.

3.3.4 Example Case: Plattsburgh AFB

Plattsburgh AFB is used to illustrate the economic assessment method used to screen the Air Force sites. The central heating plant at Plattsburgh has six boilers, each designed to burn residual (No. 6) fuel oil and produce 50 MBtu/h of pressurized hot water. The peak demand is about 195 MBtu/h and the year-round average load is ~95 MBtu/h.

A choice of size for the coal-fired system must be made. If the original boilers are going to be utilized without lowering their individual heating capacities, the choice is between 50, 100, 150 MBtu/h, etc., up to 300 MBtu/h if all six boilers are used. Replacement of boiler capacity could be done with boilers of capacities other than 50 MBtu/h, but this is a very common size and is roughly the maximum size for coal-fired packaged boilers. It was found that the best economic results measured by the benefit/cost ratio were obtained for the 50-MBtu/h case, although conversion of 100 MBtu/h (two boilers) of capacity gave similar results for the benefit/cost ratio and greater total LCC savings.

The results for analysis of the 50-MBtu/h case for Plattsburgh AFB are shown in a summary spreadsheet (the computer program output) in Table 7. The first half of the table shows the input data for that particular AFB, while the lower half compares the LCC costs of the various coal technology options and gas/oil burning. The column labeled as "Benefit/cost ratio" shows the ratio of the LCC for continued operation of a 50-MBtu/h boiler firing residual oil to the LCC of 12 different 50-MBtu/h coal utilization projects.

According to Table 7, the most cost-effective coal project at Plattsburgh AFB would employ micronized coal technology. Other coal

Table 7. Illustration of project assessment: Plattsburgh AFB

PLATTSBURGH AFB: 1 X 50 MBtu/h, WITHOUT SO_2 CONTROL

Total steam/hot water output	= 50.0 MBtu/h
Boiler capacity factor	= 0.790
Number of units for refit	= 1
Hydrated lime price($/ton)	= 40.00
Ash disposal price ($/ton)	= 10.00
Electric price (cents/kWh)	= 6.30
Labor rate (k$/year)	= 35.00
Limestone price ($/ton)	= 20.00
FUEL PRICES	
Natural gas price ($/MBtu)	= 0.00
#2 Oil price ($/MBtu)	= 0.00
#6 Oil price ($/MBtu)	= 3.67
OPTIONS	
Soot blower multiplier	= 0.0
Tube bank mod multiplier	= 1.0
Bottom ash pit multiplier	= 1.0
SO_2 control multiplier	= 0.0
LIMESTONE/LIME	
Inert fraction	= 0.05
ECONOMIC PARAMETERS	
Project life (year)	= 30
Discount rate (%/year)	= 10
Uniform pres worth factor	= 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction	= 0.100	0.090
Sulfur fraction	= 0.025	0.022
HHV (Btu/lb)	= 12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu)	= 1.50
Stoker coal ($/MBtu)	= 1.75
Coal/H_2O mix ($/MBtu)	= 3.00
Coal/oil mix ($/MBtu)	= 3.50

Primary fuel is 1
#6 FUEL OIL
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest-ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	3.67	0.0	632.5	1587.4	20926.6	<-- Primary fuel	
Micronized coal refit	1	0.800	1.50	2482.6	1008.7	648.8	18107.3	1.156	18,022
Slagging burner refit	1	0.800	1.50	4298.4	1008.7	648.8	19923.1	1.050	18,022
Modular FBC refit	1	0.790	1.50	4941.7	967.4	657.0	20254.3	1.033	18,250
Stoker firing refit	Not applicable because existing boiler was designed for #6 oil								
Coal/water slurry	1	0.750	3.00	2514.0	885.8	1384.1	23911.7	0.875	19,223
Coal/oil slurry	1	0.780	3.50	2068.5	788.7	1552.7	24140.6	0.867	8,318
Low Btu gasifier refit	1	0.679	1.75	4034.2	1097.6	892.3	22792.6	0.918	20,396
Packaged shell stoker	1	0.760	1.75	3434.5	952.9	796.8	19928.7	1.050	18,212
Packaged shell FBC	1	0.760	1.50	4376.8	968.1	682.9	19940.7	1.049	18,970
Field erected stoker	1	0.800	1.75	6247.5	940.4	756.9	22248.3	0.941	17,301
Field erected FBC	1	0.800	1.50	6858.9	1021.5	648.8	22604.7	0.926	18,022
Pulverized coal boiler	1	0.820	1.50	7271.5	1050.9	633.0	23144.9	0.904	17,582
Circulating FBC	1	0.810	1.50	8147.7	1029.8	640.8	23896.0	0.876	17,799

technologies that are seen as more cost effective than oil firing (under the given set of assumptions) include slagging burner refit, modular FBC refit, a packaged shell stoker boiler, and a packaged shell FBC boiler. The refit to stoker firing option only applies to boilers that were built as stokers and does not apply in this case because the existing boilers are designed for residual oil. It should be noted that certain factors such as risk and pollution control have not been dealt with.

3.4 LIFE-CYCLE COST ANALYSIS RESULTS

Coal-firing projects were evaluated for each of the 26 central heating plants listed in Table 1 in the same manner as the Plattsburgh AFB example explained in the previous section. The results are summarized in Table 8. Details concerning the Air Force installations and results for individual project scenarios are given in the Appendix. The

Table 8. Summary of benefit/cost ratios derived from the life-cycle cost analysis results

Base	COM[a]	Building No.	Benefit/cost ratio		Next best technology
			Micronized coal	Next best option	
Elmendorf	AAC	22-004	0.951	0.872	Slagging combustor
USAF Academy	AFA	2560	1.063	0.949	Slagging combustor
Hill	AFLC	260	0.909	0.829	Packaged stoker
Hill	AFLC	825	0.806	0.749	Packaged stoker
Kelly	AFLC	376	1.203	1.100	Packaged stoker
McClellan	AFLC	367	1.039	0.943	Packaged stoker
Robins	AFLC	177	1.262	1.134	Slagging combustor
Tinker	AFLC	3001	1.117	1.021	Slagging combustor
Tinker	AFLC	208	0.934	0.857	Packaged stoker/ packaged FBC
Arnold	AFSC	1411	1.219	1.095	Slagging combustor
Hanscom	AFSC	1201	1.187	1.081	Slagging combustor
Keesler	ATC	409	0.900	0.842	Packaged stoker
Lowry	ATC	361	0.896	0.844	Stoker refit
Maxwell	AU	1410	0.941	0.868	Packaged stoker/ packaged FBC
Andrews	MAC	1515/1732	1.089	1.015	Stoker refit
Charleston	MAC	431	0.878	0.831	Stoker refit
Dover	MAC	617	1.043	0.980	Stoker refit
McChord	MAC	734	0.885	0.823	Stoker refit
McGuire	MAC	2101	1.105	1.041	Stoker refit
Scott	MAC	45	1.056	0.989	Stoker refit
Grand Forks	SAC	423	1.080	1.007	Stoker refit
Minot	SAC	413	1.141	1.063	Stoker refit
Pease	SAC	124	1.139	1.022	Slagging combustor
Plattsburgh	SAC	2658	1.156	1.050	Slag combustor/ packaged stoker
Whiteman	SAC	140	0.866	0.793	Packaged stoker
Wurtsmith	SAC	305	0.986	0.929	Stoker refit

[a]Air Force Major Command.

results will be examined and interpreted with the goal of eliminating several more heating plants from consideration.

3.4.1 Examination of the Results

The results given in Table 8 are in terms of the benefit/cost ratio explained in Sect. 4.3.3. Two sets of benefit/cost values are given for each heating plant examined. One set of values represents the application of micronized coal firing as a refit technology and the other is the technology giving the next highest benefit/cost ratio (labeled "Next best option" in Table 8). The results identified micronized coal firing as the coal technology with the highest benefit/cost ratio for all sites.

Potential cost savings from micronized coal firing. The results consistently point to micronized coal firing as the most economical system. Micronized coal systems appear attractive due to low capital investment requirements and because run-of-mine coal can be used instead of more expensive stoker-grade coal. It should be noted that the analysis did not include air quality constraints and does not fully account for the level of risk or uncertainty associated with micronized coal firing. The results should certainly not be interpreted to mean that micronized coal will always be the best choice for coal-fired systems. More in-depth studies are required to come to conclusions concerning which technologies are the most promising for an individual heating plant, and this was not the objective of the analysis presented in this report.

Potential cost savings for the "next best" option. It is likely that micronized coal technology is not applicable to some of the boiler plants examined, and for this reason the "next best" technology results were also identified. This refers to whatever applicable technology was calculated to have the second highest benefit/cost ratio at each site. Note from Table 8 that this "next best" technology varied from site to site. Slagging combustor refit, stoker refit, and packaged stoker boilers were the most common "next best" technology choices. Often, several technologies gave very similar benefit/cost ratio results, and in a few cases the results for two technologies were virtually identical; therefore, two technologies are listed in Table 8.

3.4.2 Potential of Heating Plants to Use Coal

The objective of performing the LCC analysis presented in this report is to have a tool to assist in shortening the list of Air Force heating plants under consideration. By examining the analysis results, heating plants with very little potential for coal use may be identified. Heating plants showing the poorest economic potential for the relatively small types of projects considered in the analysis can be easily identified from Table 9. Reducing the list of plants is not simply a matter of eliminating these heat plants from consideration; first, a number of questions should be answered to determine if the particular heating plant has potential for other types of coal utilization projects, especially cogeneration of heat and electricity.

If a plant has a relatively large heat load, has a large electric load, or must pay a high price for electricity, perhaps some alternative coal project could show some promise. Data pertaining to the heating plants that may be relevant to this matter are shown in Tables 10 and 11.

Ranking the heating plants. The heating plants have been ranked in Table 9 by the benefit/cost ratios presented in Table 8. Two rankings are given, one for use of micronized coal technology and one for the "next best" technology. From Table 9, the heating plants with high or low potential for coal use can be identified.

Fifteen sites were identified with a benefit/cost ratio >1.0 for micronized coal-firing technology, and 11 sites for the "next best" technology. The "top 11" sites are the same for micronized coal technology and the "next best" technology cases, although the order is somewhat different. There seems to be no reason to eliminate any of these "top 11" sites from further consideration at this point.

Using similar reasoning, heating plants can be identified that have benefit/cost ratios <1.0 for both cases given in Table 9. It seems reasonable to consider eliminating these plants from further consideration. Included in this category (plant building numbers are given when needed) are Wurtsmith, Elmendorf, Maxwell, Tinker No. 208, Hill No. 260, and No. 825, Keesler, Lowry, McChord, Charleston, and Whiteman. These plants can be referred to as the "bottom 11."

Table 9. Heating plants ranked by benefit/cost ratio

Micronized coal technology cases				Next best technology cases			
Rank	Base	Building No.	Benefit/cost ratio	Rank	Base	Building No.	Benefit/cost ratio
1	Robins	177	1.262	1	Robins	177	1.134
2	Arnold	1411	1.219	2	Kelly	376	1.100
3	Kelly	376	1.203	3	Arnold	1411	1.095
4	Hanscom	1201	1.187	4	Hanscom	1201	1.081
5	Plattsburgh	2658	1.156	5	Minot	413	1.063
6	Minot	413	1.141	6	Plattsburgh	2658	1.050
7	Pease	124	1.139	7	McGuire	2101	1.041
8	Tinker	3001	1.117	8	Pease	124	1.022
9	McGuire	2101	1.105	9	Tinker	3001	1.021
10	Andrews	1515/1732	1.089	10	Andrews	1515/1732	1.015
11	Grand Forks	423	1.080	11	Grand Forks	423	1.007
12	USAF Academy	2560	1.063	12	Scott	45	0.989
13	Scott	45	1.056	13	Dover	617	0.980
14	Dover	617	1.043	14	USAF Academy	2560	0.949
15	McClellan	367	1.039	15	McClellan	367	0.943
16	Wurtsmith	305	0.986	16	Wurtsmith	305	0.926
17	Elmendorf	22-004	0.951	17	Elmendorf	22-004	0.872
18	Maxwell	1410	0.941	18	Maxwell	1410	0.868
19	Tinker	208	0.934	19	Tinker	208	0.857
20	Hill	260	0.909	20	Lowry	361	0.844
21	Keesler	409	0.900	21	Keesler	409	0.842
22	Lowry	361	0.896	22	Charleston	431	0.831
23	McChord	734	0.885	23	Hill	260	0.829
24	Charleston	431	0.878	24	McChord	734	0.823
25	Whiteman	140	0.866	25	Whiteman	140	0.793
26	Hill	825	0.806	26	Hill	825	0.749

Table 10. Heating plant characteristics ranked by fuel use

Base	Building No.	Estimated[a] annual fuel use (BBtu/year)	Primary fuel	Primary fuel cost ($/MBtu)	Boiler design fuel	Boiler plant condition
Elmendorf	22-004	2650	Gas	2.05	Coal	Good
Tinker	3001	1375	Gas	2.85	No. 2 Oil	
Hill	260	1100	Gas	2.97	No. 2 Oil	Excellent
Robins	177	900	Gas	3.90	Coal	
Plattsburgh	2658	825	No. 6 Oil	3.67	No. 6 Oil	Fair
USAF Academy	2560	800	Gas	3.50	No. 5 Oil	Excellent
Hanscom	1201	800	No. 6 Oil	3.67	No. 6 Oil	Fair
McGuire	2101	800	Gas	4.00	Coal	Fair
Tinker	208	660	Gas	2.85	No. 2 Oil	
Arnold	1411	610	Gas	3.97	Coal	Fair
Grand Forks[b]	423	550	No. 6 Oil	3.67	Coal	Poor
Andrews	1515/1732	540	No. 6 Oil	3.67	Coal	Fair
Kelly	376	540	Gas	4.00	No. 2 Oil	Good
Minot	413	500	Gas	4.18	Coal	Good
Scott	45	440	Gas	3.80	Coal	Poor
Dover	617	425	No. 6 Oil	3.67	Coal	Excellent
Pease	124	380	Gas	3.80	No. 6 Oil	Good
Maxwell	1410	360	Gas	3.40	No. 5 Oil	Good
McClellan	367	340	Gas	3.92	No. 5 Oil	
McChord	734	340	Gas	2.90	Coal	Good
Wurtsmith	305	320	No. 6 Oil	3.67	Coal	Fair
Whiteman	140	310	Gas	3.00	No. 6 Oil	
Hill	825	300	Gas	2.97	No. 2 Oil	Excellent
Keesler	409	300	Gas	3.63	No. 2 Oil	Good
Lowry	361	230	Gas	3.42	Coal	Excellent
Charleston	431	175	No. 6 Oil	3.67	Coal	Fair

[a]Estimated from information in Table 1.

[b]Grand Forks presently uses electric boilers to meet steam demand, and the residual oil-fired boilers are idle. The value given for fuel consumption assumes oil firing.

Table 11. Air Force base electric consumption and cost

Base	Annual electric consumption (MWh/year)	Cost of electricity (¢/kWh)
Elmendorf	90,500	3.50
USAF Aacademy	81,900	3.50
Hill	192,900	5.20
Kelly	248,800	5.10
McClellan	258,600	3.50
Robins	196,100	4.40
Tinker	263,000	4.80
Arnold	482,500	4.50
Hanscom	62,000	6.10
Keesler	142,700	4.50
Lowry	71,000	4.30
Maxwell	62,600	5.40
Andrews	137,500	5.00
Charleston	74,800	4.50
Dover	63,700	6.60
McChord	76,700	1.64
McGuire	74,700	7.80
Scott	70,800	4.90
Grand Forks	81,400	2.15
Minot	71,400	3.20
Pease	44,500	6.00
Plattsburgh	49,000	5.00
Whiteman	61,000	4.80
Wurtsmith	40,000	5.26

Four central heating plants are left that have not been identified in either the "top 11" or "bottom 11" categories. These plants, which are the central plants at the USAF Academy and Scott, Dover, and McClellan AFBs, should be given further review.

3.4.3 Heating Plants Dropped from Consideration

Using the information in Tables 9–11, decisions can be made whether to eliminate certain heating plants that show the least economic potential for coal utilization. In this section, the list of candidate plant conversions is further reduced from 26 to 16. Tables 10 and 11 can be used to identify heating plants that have characteristics favorable or unfavorable to coal utilization that may not be reflected by the economic analysis.

Six heat plants can be identified that show very little promise for coal use. All have relatively small electric and heat loads, have moderate to low electric rates, and had low benefit/cost ratios in the LCC presented earlier. It is recommended that the central heating plants be dropped from further consideration at Whiteman, Charleston, McChord, Lowry, Maxwell, and Wurtsmith AFBs.

Several other heat plants are recommended for elimination at this point but require some explanation. Each plant is dealt with separately in the following text.

Hill AFB No. 825. Hill AFB has two heating plants under scrutiny in this study, and the base uses a relatively large amount of electricity. Heating plant No. 825 uses about 300 BBtu/year and plant No. 260 uses about 1100 BBtu/year. It is obvious from the heating loads that the smaller plant will not be attractive for coal, and any large project involving cogeneration would involve the larger plant. Heating plant No. 825 is therefore dropped from the list, but Hill AFB plant No. 260 is retained for future consideration.

Keesler AFB. The central heating plant at Keesler AFB is quite small (34 MBtu/h average heat load), but Keesler does consume a relatively large amount of electricity (143,000 MWh/year). Considering the price of electricity is moderate at 4.5¢/kWh, it would be quite difficult for coal to be viable for cogeneration unless fuel and electric costs changed significantly. Keesler is recommended to be dropped from further consideration.

McClellan AFB. The central heating plant at McClellan AFB is small, but the base uses a relatively large quantity of electricity (250,600 MWh/year). Because electric rates are low (3.5¢/kWh), cogeneration projects are not economically viable. The results of the LCC analysis did give this site at least a marginal benefit/cost ratio for micronized coal firing; however, the local environmental regulations are very strict (McClellan is located in a California nonattainment area),[1] and this is not properly accounted for in the analysis. Because of the strict regulatory climate, it is judged that coal utilization cannot be competitive, and this plant should be dropped from consideration.

Tinker AFB No. 208. Heating plant No. 208 consumes a large amount of fuel, and therefore Tinker AFB may be a reasonable site for cogeneration. However, an unfavorable benefit/cost ratio was calculated in the economic analysis. Heating plant No. 3001 is much larger (consumes more than twice as much fuel) and fared much better in the LCC analysis. Because of this larger plant, Tinker AFB will remain as a site for further consideration. It is recommended that heat plant No. 208 be removed from the list with one contingency: if large coal utilization projects are examined for Tinker AFB in further studies, projects that include or replace both heating plant No. 208 and No. 3001 will be considered.

The list of plants that should be given closer study has now been reduced from 26 to 16. Some justification for keeping selected plants on this list are given in the next section.

3.4.4 Heating Plants that Warrant Further Consideration

A number of heating plants examined by the LCC analysis show enough promise to justify further study. All plants for which the benefit/cost ratio was greater than 1.0 for both micronized coal and the "next best" technology (Table 9) are recommended for further examination. These plants include the major central heat plant at the following AFBs: Robins, Arnold, Kelly, Hanscom, Plattsburgh, Minot, Pease, Tinker (No. 3001), McGuire, Andrews, and Grand Forks.

USAF Academy, Scott AFB, and Dover AFB. The main heat plants at these sites are borderline cases according to the LCC analysis. It was judged prudent to retain these sites for subsequent study, especially considering that the list of sites has been shortened to a satisfactory number.

A few facts can be cited that support retaining the Academy and Dover AFB. The main heating plant at the Academy is among the top eight fuel-consuming plants examined (Tables 10 and 11). Electricity at Dover

AFB is priced near 6.6¢/kWh, with electric consumption near 64,000 MWh/year. There is some promise for a small cogeneration project at Dover.

Elmendorf AFB. The main heat plant at Elmendorf is the largest fuel-using facility under consideration. The reason the economic analysis results are relatively poor (ranked 17 in Table 9) is because of very low-priced natural gas currently available (about $2.05/MBtu), a situation that could easily change. Coal might be attractive if gas prices were more typical. It is recommended that this particular plant remain under consideration.

Hill AFB No. 260. Heat plant No. 260 at Hill AFB is the third largest fuel consumer considered. Hill is also a large electric user (193,000 MWh/year) at a cost near 5.2¢/kWh. The poor economic results are because of the availability of gas at under $3.0/MBtu. Further consideration of this plant is recommended because of its potential for cogeneration and because coal may be attractive if gas prices rose to a more typical value.

3.4.5 Reduced List of Candidate Heating Plants

With the elimination of 10 heating plants from further consideration, 16 plants located at 16 different Air Force sites remain for further review. A summary of these remaining heating plants is presented in Table 12.

After reviewing the remaining heating plants, it was concluded that no others can be eliminated with a high level of confidence. Rather than reduce the list further, it appears better to concentrate on refining information and performing more detailed analyses in future work. A discussion concerning the potential of the remaining heat plants to use coal and of further work to be done is given in the next sections.

Table 12. Remaining heating plants ranked by fuel use

Base	Building No.	Estimated annual fuel use (BBtu/year)	Primary fuel	Primary fuel cost ($/MBtu)	Potential coal use (tons/year)
Elmendorf	22-004	2650	Gas	2.05	60,200
Tinker	3001	1375	Gas	2.85	37,600
Hill	260	1100	Gas	2.97	19,900
Robins	177	900	Gas	3.90	25,900
Plattsburgh	2658	825	No. 6 Oil	3.67	18,000
McGuire	2101	800	Gas	4.00	13,700
USAF Academy	2560	800	Gas	3.50	18,300
Hanscom	1201	800	No. 6 oil	3.67	19,400
Arnold	1411	610	Gas	3.97	19,700
Grand Forks[a]	423	550	No. 6 Oil	3.67	13,600
Andrews	1515/1732	540	No. 6 Oil	3.67	15,900
Kelly	376	540	Gas	4.00	17,100
Minot	413	500	Gas	4.18	12,200
Scott	45	440	Gas	3.80	11,900
Dover	617	425	No. 6 Oil	3.67	13,500
Pease	124	380	Gas	3.80	17,900

Total fuel consumption = 13,235 BBtu/year
Total potential coal use = 334,800 tons/year

[a]Grand Forks presently uses electric boilers to meet steam demand, and the residual oil-fired boilers are idle. The value given for fuel consumption assumes oil firing.

4. OTHER CONSIDERATIONS

4.1 COMPARISON WITH ORI, INC./C. H. GUERNSEY & CO. RESULTS

The ORI, Inc./C. H. Guernsey & Co. study (Sect. 2.1) recommended 12 AFBs as the "most favorably ranked" sites for coal use. These 12 sites were chosen based on a detailed matrix ranking scheme that examined important heating plant and energy use parameters. However, this list of 12 sites was developed before performing an LCC analysis of potential coal utilization projects. Included among these 12 sites were the heat plants at McChord and Seymour Johnson AFBs, both of which were eliminated from the list of bases under consideration in this report. The other 10 AFBs recommended by ORI, Inc./C. H. Guernsey & Co. coincide with the heat plant sites chosen by ORNL for further consideration in this study.

The ORI, Inc./C. H. Guernsey & Co. study includes an economic analysis for each of the 12 sites recommended for coal use. Based on the economic analysis, seven sites were chosen as most suitable for coal utilization: Elmendorf, USAF Academy, Hill, Kelly, Robins, Arnold, and Plattsburgh. All seven of these sites have also been selected in this report. Although the approach used in the ORI, Inc./C. H. Guernsey & Co. study was much different, the results of that study do not seriously conflict with the findings of this report.

4.2 POTENTIAL COAL USE

The provisions of the Defense Appropriations Act of 1986 (PL 99-190 Section 8110) directs the DOD to implement the rehabilitation and conversion of central heating plants to coal firing, where a cost benefit can be realized. The coal utilization target set by this Act is 1,600,000 short tons per year above current use by 1995. It is of interest to examine the potential impact the projects proposed by this report would have toward meeting this goal.

If the estimated coal use for proposed projects at the 16 heating plants listed in Table 12 are summed, a total of roughly

330,000 tons/year would be consumed. If it were assumed that each boiler plant were completely converted to coal rather than just for meeting base load, a total of roughly 13,000 BBtu/year of coal would be consumed, which translates into about 520,000 tons of coal/year (average coal heating value of 12,500 Btu/lb).

It is certain that completely converting these heating plants to coal firing will not be economical for most sites unless fuel prices change rather drastically. Only a subset of the 16 conversion projects represented in Table 12 are likely to be considered economically viable after future detailed studies are completed. Increased coal use of significantly <330,000 tons/year would be expected before 1995 by pursuing the projects examined in this study. It is concluded that other types of coal utilization projects should also be explored if any large portion of the 1,600,000-tons/year target is to be met without an economic loss to the Air Force. Suggested project categories include cogeneration and expansion of heating systems at sites where coal is currently the main fuel.

5. CONCLUSIONS AND RECOMMENDATIONS

Sixteen Air Force heating plants have been chosen as the best candidates for coal utilization from among the Air Force facilities located in the contiguous United States and Alaska. These are all facilities that normally use more than 350 BBtu/year of oil or gas (with the exception of Grand Forks AFB, which currently uses electric boilers). It is doubtful that any individual steam or hot water plants of this size have been overlooked; if so, they should be reviewed for consideration in subsequent studies.

It is likely that several of these 16 chosen heat plants could use coal at a cost savings. This subject will be explored in greater detail in a subsequent study.[9] The 1,600,000-tons/year target for additional coal use by DOD over 1986 coal consumption levels would be impacted by 330,000 tons/year, assuming projects are implemented at the 16 selected sites. It is unlikely that all such projects would in reality be economical, even when considering the 1995 time frame; therefore, the projected coal use impact would be smaller than 330,000 tons/year. To achieve larger coal use it is recommended that cogeneration, plant expansion, and other types of projects be explored.

The 16 candidate heating plants are examined further in a companion study,[9] which involves verification of data pertaining to these facilities and gathering more detailed information to take a closer look at each facility. In particular, the cost and specifications of coal available at each site must be estimated, and the environmental constraints and site-specific limitations should be thoroughly understood. Fuel price escalation should also be explored in subsequent work.

In subsequent studies a variety of project types should be examined, including a full range of technologies and cogeneration schemes. The study by ORI, Inc./C. H. Guernsey & Co. examined only a very narrow range of coal technologies and project scenarios. This range should be expanded to find more optimum projects from an economic standpoint. Projects such as plant expansion at coal-fired facilities and a broad range of cogeneration schemes should be explored.

After examining the 16 chosen heating plants and possible coal utilizing projects in more detail, the best sites for coal conversion will be identified. This will allow a small number of "top candidate" sites to be considered for a first project and/or for a demonstration site.

REFERENCES

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2. J. F. Thomas and J. M. Young, *Coal Burning Technologies Applicable to Air Force Central Heating Plants*, ORNL/TM-11173, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., sponsored by Headquarters, Air Force Engineering and Services Center, Tyndall AFB, Fla., to be issued 1989.

3. M. C. Reynolds, Lieutenant General, USAF, Vice Commander, AFLC, Letter report to HQ USAF/LE, energy data sheets for fiscal year 1985, including Hill, Kelly, McClellan, and Robins AFBs, March 3, 1986.

4. Energy data summaries for calendar year 1985 from Military Airlift Command, including Andrews, Charleston, Dover, Kirtland, McChord, McGuire, Norton, and Scott AFBs.

5. Energy data summaries for calendar years 1984 and 1985 from Strategic Air Command, including Grand Forks, Minot, Pease, Plattsburgh, and Wurtsmith AFBs.

6. A. E. Margulies, *Economic Evaluation of Microfine Coal-Water Slurry*, EPRI CS-4975, Stone & Webster, prepared for Electric Power Research Institute, Palo Alto, Calif., December 1986, pp. 3–4.

7. B. C. Lippiatt and R. T. Ruegg, *Energy Prices and Discount Factors for Life Cycle Cost Analysis: Annual Supplement to NBS Handbook 135 and Special Publication 709*, NBSIR 85-3273-2, U.S. Department of Commerce, National Bureau of Standards, prepared for U.S. Department of Energy.

8. *Air Force Life Cycle Costing Handbook for the Energy Conservation Investment Programs*, Headquarters Air Force Engineering and Services Center, Energy Group, Tyndall AFB, Fla., April 1, 1986, Rev. 1.

9. F. P. Griffin, J. F. Thomas, R. S. Holcomb, and J. M. Young, *Ranking of Air Force Heating Plants Relative to the Economic Benefit of Coal Utilization*, ORNL/TM-11100, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., sponsored by Headquarters, Air Force Engineering and Services Center, Tyndall AFB, Fla., to be issued 1989.

Appendix A

ECONOMIC ANALYSIS: INPUT AND RESULTS

This appendix contains the input data for and the results of the economic analyses performed on each of the 24 Air Force bases considered for conversion to coal utilization. The bases are alphabetized and grouped according to command (e.g., AAC, AFLC, etc.).

The input data for each Air Force base are broken up into the following six sections.

1. BACKGROUND

This section gives the location of the Air Force base and the number and types of boilers present. The primary and (if used) secondary fuels are identified, along with the average fuel use and load. Another important aspect discussed is whether or not any of the boilers previously burned coal and when any conversion to alternate fuels took place.

2. HEATING PLANT UNITS

In this section, the number of boilers at the base are specified, along with each boiler's rating, maker, and year of construction.

3. IDEAL CAPACITY FACTOR ANALYSIS

The ideal capacity (or load) factor is defined as the total amount of heat a boiler produces in 1 year divided by the total amount of heat that same boiler could produce in 1 year if it were operated at its design output capacity (maximum continuous rating). The tables in this section list the expected capacity factors for each coal project size considered. These expected capacity factors are computed from actual load data for the heating plants from previous years.

4. ENERGY PRICES

The costs to the Air Force for electricity, natural gas, and oil at each base are listed in this section. These prices were obtained from the FY 1986 Defense Energy Information System data base and the C. H. Guernsey & Co. survey.

5. OTHER CONSIDERATIONS

This section contains any information not specified in the previous sections that may be pertinent in determining the possibility of converting a boiler plant to coal firing. For example, whether or not an Air Force base is located in an area governed by strict environmental regulations will influence the feasibility for coal use at that base.

6. COAL CONVERSION PROJECT OUTLOOK

In this section, the best options for coal conversion at the base are listed, along with the load factors that would be obtained by each option.

The outcome of the economic analysis for each base is presented after the input data. The results show the life-cycle cost and benefit/cost ratio for each potential coal conversion scenario.

ELMENDORF AFB: AAC

1. BACKGROUND

Elmendorf Air Force Base is located near Anchorage, Alaska, and has one of the largest central heating plants in the Air Force. The annual fuel consumption is ~2600 BBtu/year. Only the primary heating plant (Bldg. 22-004) is significant to this study.

The main heating plant has six coal-designed boilers built in 1954 that produce 415 psig superheated steam. All boilers are rated at 150 MBtu/h output heat and were built to burn bituminous or subbituminous coals. They are described as Erie City, field-erected, two-drum, bent-tube, water-tube units with economizers, fitted with Peabody ring-type gas burners and Peabody steam-atomizing oil burners. Natural gas is now the main fuel, with distillate (arctic diesel) oil as a backup fuel. The boilers previously burned Matanuska coal with spreader stoker traveling grate systems. Conversion to natural gas (with arctic diesel as the secondary fuel) took place in 1968. The Matanuska mines went out of business because the remaining coal seam dipped steeply, causing mining to be uneconomical, especially in comparison with natural gas.

Presently, cogeneration is used at this steam plant. The superheated steam passes through three Westinghouse 9375-kVA condensing, single automatic extraction turbogenerators. Steam is extracted at 100 psig.

2. IDEAL CAPACITY FACTOR ANALYSIS

Plant No. 22-004

Fuel input (MBtu/h)	FY 1979 Ideal capacity factor
250	0.97
300	0.90
350	0.83
400	0.76
450	0.685
500	0.62

3. ENERGY PRICES

FY 1986 Price Data

Gas prices averaged about $1.94/MBtu in FY 1986 but were as high as $2.60/MBtu in September, according to the DEIS data. Distillate oil cost $5.90/MBtu in 1986. Electric prices averaged 8.0¢/kWh but seemed to increase near the end of the fiscal year. The purchased electric load was small: 600 MWh/year, costing about $48,000. This probably does not include any of the electricity generated by the cogeneration system on the base. Fuel use was 2,091,000 and 134,000 MBtu for natural gas and distillate oil, respectively. Average fuel use was about 250 MBtu/h. Coal is used at Eielson AFB in Alaska at a cost near $2.8/MBtu.

C. H. Guernsey & Co. Survey

The price of gas is ~$2.05/MBtu, oil (arctic diesel) is ~$5.9/MBtu, and electricity is 3.5¢/kWh (this disagrees with the DEIS data).

4. OTHER CONSIDERATIONS

Wages for steam plant personnel look very high, about $17/h in 1980. Nineteen people were listed as the main boiler plant personnel.

Coal has some special problems in Alaska because of freezing temperatures and transportation difficulties. Coal costs seem much higher than are typical in the United States.

5. COAL CONVERSION PROJECT OUTLOOK

A conversion project would involve replacement or refit of the existing six 150-MBtu/h boilers. Based on the capacity factor analysis, the most economical coal options would probably be to replace/refit two or three boilers. Because natural gas prices are low ($2.00–$2.60/MBtu), the best economic option is to continue natural gas firing. Coal prices are suspected to be quite high in Alaska, but this has not been accurately documented.

The maximum load factor for conversion/replacement of two 150-MBtu/h units (375 MBtu/h fuel input for both units) would be ~0.80. If 90% coal system availability is assumed, then a realistic plant load factor for coal firing would be 70%.

Table A.1. Elmendorf AFB: 1 x 150 MBtu/h, without SO_2 control

Total steam/hot water output	= 150.0 MBtu/h
Boiler capacity factor	= 0.880
Number of units for refit	= 1
Hydrated lime price($/ton)	= 40.00
Ash disposal price ($/ton)	= 10.00
Electric price (cents/kWh)	= 3.50
Labor rate (k$/year)	= 35.00
Limestone price ($/ton)	= 20.00
FUEL PRICES	
Natural gas price ($/MBtu)	= 2.05
#2 Oil price ($/MBtu)	= 0.00
#6 Oil price ($/MBtu)	= 0.00
OPTIONS	
Soot blower multiplier	= 0.0
Tube bank mod multiplier	= 0.0
Bottom ash pit multiplier	= 1.0
SO_2 control multiplier	= 0.0
LIMESTONE/LIME	
Inert fraction	= 0.05
ECONOMIC PARAMETERS	
Project life (year)	= 30
Discount rate (%/year)	= 10
Uniform pres worth factor	= 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction	= 0.100	0.090
Sulfur fraction	= 0.025	0.022
HHV (Btu/lb)	= 12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu)	= 1.50
Stoker coal ($/MBtu)	= 1.75
Coal/H_2O mix ($/MBtu)	= 3.00
Coal/oil mix ($/MBtu)	= 3.50

Primary fuel is 3
NATURAL GAS
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest-ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	2.05	0.0	917.8	2963.1	36584.9	<-- Primary fuel	
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	1	0.800	1.50	4535.4	1433.7	2168.1	38489.1	0.951	60,225
Slagging burner refit	1	0.800	1.50	7987.3	1433.7	2168.1	41941.0	0.872	60,225
Modular FBC refit	1	0.790	1.50	9202.4	1357.9	2195.5	42700.7	0.857	60,987
Stoker firing refit	1	0.760	1.75	5308.7	1328.4	2662.6	42931.4	0.852	60,859
Coal/water slurry	1	0.750	3.00	4167.3	1252.6	4625.3	59577.4	0.614	64,240
Coal/oil slurry	1	0.780	3.50	3764.9	1092.9	5188.6	62980.0	0.581	27,796
Low Btu gasifier refit	3	0.679	1.75	10892.3	1768.9	2982.0	55678.6	0.657	68,159
Packaged shell stoker	3	0.760	1.75	9273.2	1502.5	2662.6	48536.8	0.754	60,859
Packaged shell FBC	3	0.760	1.50	11817.3	1534.4	2282.2	47796.3	0.765	63,395
Field erected stoker	1	0.800	1.75	12317.5	1305.6	2529.5	48470.0	0.755	57,816
Field erected FBC	1	0.800	1.50	13682.2	1437.9	2168.1	47676.0	0.767	60,225
Pulverized coal boiler	1	0.820	1.50	14405.2	1468.9	2115.2	48192.4	0.759	58,756
Circulating FBC	1	0.810	1.50	17001.7	1452.6	2141.3	50881.1	0.719	59,481

Table A.2. Elmendorf AFB: 2 x 150 MBtu/h, without SO_2 control

Total steam/hot water output	= 300.0 MBtu/h
Boiler capacity factor	= 0.700
Number of units for refit	= 2
Hydrated lime price($/ton)	= 40.00
Ash disposal price ($/ton)	= 10.00
Electric price (cents/kWh)	= 3.50
Labor rate (k$/year)	= 35.00
Limestone price ($/ton)	= 20.00
FUEL PRICES	
Natural gas price ($/MBtu)	= 2.05
#2 Oil price ($/MBtu)	= 0.00
#6 Oil price ($/MBtu)	= 0.00
OPTIONS	
Soot blower multiplier	= 0.0
Tube bank mod multiplier	= 0.0
Bottom ash pit multiplier	= 1.0
SO_2 control multiplier	= 0.0
LIMESTONE/LIME	
Inert fraction	= 0.05
ECONOMIC PARAMETERS	
Project life (year)	= 30
Discount rate (%/year)	= 10
Uniform pres worth factor	= 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction	= 0.100	0.090
Sulfur fraction	= 0.025	0.022
HHV (Btu/lb)	= 12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu)	= 1.50
Stoker coal ($/MBtu)	= 1.75
Coal/H_2O mix ($/MBtu)	= 3.00
Coal/oil mix ($/MBtu)	= 3.50

Primary fuel is 3
NATURAL GAS
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest- ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	-	0.800	2.05	0.0	1209.5	4714.0	55840.3	<-- Primary fuel	
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	2	0.800	1.50	8390.5	1982.8	3449.3	59598.3	0.937	95,813
Slagging burner refit	2	0.800	1.50	14776.5	1982.8	3449.3	65984.3	0.846	95,813
Modular FBC refit	2	0.790	1.50	17024.4	1857.8	3492.9	67464.9	0.828	97,025
Stoker firing refit	2	0.760	1.75	9821.0	1810.8	4235.9	66823.0	0.836	96,821
Coal/water slurry	2	0.750	3.00	7709.6	1713.3	7358.4	93227.8	0.599	102,200
Coal/oil slurry	2	0.780	3.50	6965.0	1496.4	8254.6	98886.8	0.565	44,221
Low Btu gasifier refit	6	0.679	1.75	21179.5	2529.0	4744.0	89741.9	0.622	108,435
Packaged shell stoker	6	0.760	1.75	18031.3	2040.5	4235.9	77198.4	0.723	96,821
Packaged shell FBC	6	0.760	1.50	22978.1	2091.3	3630.8	76919.6	0.726	100,855
Field erected stoker	1	0.800	1.75	19110.8	1653.6	4024.1	72633.9	0.769	91,980
Field erected FBC	1	0.800	1.50	21366.6	1841.4	3449.3	71241.2	0.784	95,813
Pulverized coal boiler	1	0.820	1.50	22386.1	1866.4	3365.1	71703.0	0.779	93,476
Circulating FBC	1	0.810	1.50	27332.3	1868.0	3406.7	77055.9	0.725	94,630

USAF ACADEMY

1. BACKGROUND

The USAF Academy is located 10 miles north of Colorado Springs, Colorado. There are two significant boiler plants at the Academy (Bldgs. 2560 and 8026), both of which produce pressurized hot water. Natural gas is the primary fuel, and No. 5 fuel oil (150,000 MBtu/gal) is the reserve fuel. All boilers are water-tube type and were designed for oil/gas firing.

A significant amount of fuel is used at the Academy. Yearly totals for fuel consumption by both heating plants were reported to be 817 BBtu for FY 1978 and 809 BBtu for FY 1979. Heating plant No. 2560 is the larger plant and is reported to use 555 BBtu/year (C. H. Guernsey & Co. survey).

2. HEATING PLANT UNITS

Heating Plant No. 2560

3 × 100 MBtu/h; Combustion Engineering (1957)
80 MBtu/h; Boiler Engineering and Supply Co. (1968)

Heating Plant No. 8026

2 × 30 MBtu/h; National Steel (1957)
(possibly a Combustion Engineering boiler)

3. IDEAL CAPACITY FACTOR ANALYSIS

No data were available.

4. ENERGY PRICES

FY 1986 Price Data

Electricity = 3.5¢/kWh at end of year
Natural gas = $3.8/MBtu
No. 5 oil = very little purchased

C. H. Guernsey & Co. Survey

Electricity = 3.5¢/kWh
Natural gas = $3.5/MBtu
No. 5 oil = no reported value

5. OTHER CONSIDERATIONS

Heating plant No. 2560 is capable of producing 425 psig of hot water but operates at about 185 psig. The design pressure for heating plant No. 8026 is 275 psig.

It should be noted that no boilers were designed for coal firing, and there may be strict air-quality constraints and aesthetics to be considered.

6. COAL CONVERSION PROJECT OUTLOOK

Heating plant No. 2560 appears to have an average load of ~47 to 53 MBtu/h. The reported peak load for this plant is about 150 MBtu/h. Because there are no load data available, a realistic load factor can only be estimated for a given project scenario. If the 80-MBtu/h boiler were replaced or refitted for coal firing and had the same capacity, a realistic capacity factor might be about 50%.

Table A.3. USAF Academy: 1 x 80 MBtu/h, without SO_2 control

Total steam/hot water output = 80.0 MBtu/h
Boiler capacity factor = 0.500
Number of units for refit = 1
Hydrated lime price($/ton) = 40.00
Ash disposal price ($/ton) = 10.00
Electric price (cents/kWh) = 3.50
Labor rate (k$/year) = 35.00
Limestone price ($/ton) = 20.00

FUEL PRICES

Natural gas price ($/MBtu) = 3.50
#2 Oil price ($/MBtu) = 0.00
#6 Oil price ($/MBtu) = 0.00

OPTIONS

Soot blower multiplier = 1.0
Tube bank mod multiplier = 1.0
Bottom ash pit multiplier = 1.0
SO_2 control multiplier = 0.0

LIMESTONE/LIME

Inert fraction = 0.05

ECONOMIC PARAMETERS

Project life (year) = 30
Discount rate (%/year) = 10
Uniform pres worth factor = 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction =	0.100	0.090
Sulfur fraction =	0.025	0.022
HHV (Btu/lb) =	12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu) = 1.50
Stoker coal ($/MBtu) = 1.75
Coal/H_2O mix ($/MBtu) = 3.00
Coal/oil mix ($/MBtu) = 3.50

Primary fuel is 3
NATURAL GAS
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest-ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	3.50	0.0	704.1	1533.0	21088.6	<-- Primary fuel	
#2 Oil fired boiler	-	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	1	0.800	1.50	3439.2	1082.6	657.0	19838.1	1.063	18,250
Slagging burner refit	1	0.800	1.50	5826.3	1082.6	657.0	22225.2	0.949	18,250
Modular FBC refit	1	0.790	1.50	6670.1	1048.1	665.3	22822.4	0.924	18,481
Stoker firing refit	Not applicable because existing boiler was designed for #2 oil								
Coal/water slurry	1	0.750	3.00	3521.5	965.8	1401.6	25839.2	0.816	19.467
Coal/oil slurry	1	0.780	3.50	2957.0	854.5	1572.3	25834.0	0.816	8,423
Low Btu gasifier refit	2	0.679	1.75	6560.3	1224.0	903.6	26617.2	0.792	20,654
Packaged shell stoker	2	0.760	1.75	5642.5	1132.8	806.8	23927.5	0.881	18,442
Packaged shell FBC	2	0.760	1.50	7076.3	1142.5	691.6	24365.8	0.865	19,211
Field erected stoker	1	0.800	1.75	8330.5	1029.0	766.5	25256.8	0.835	17,520
Field erected FBC	1	0.800	1.50	9193.3	1112.3	657.0	25872.1	0.815	18,250
Pulverized coal boiler	1	0.820	1.50	9718.9	1148.0	641.0	26583.8	0.793	17,805
Circulating FBC	1	0.810	1.50	11130.6	1098.6	648.9	27604.0	0.764	18,025

HILL AFB: AFLC

1. BACKGROUND

Hill AFB is located near Ogden, Utah. There are about 13 steam plants located on this base, with plant No. 260 being by far the largest fuel user. Boiler plant No. 825 is the second largest fuel-using heating facility, but it is probably too small for coal to be an economic option.

Boilers at both heating plants are water-tube type units that produce 100 psi steam and are designed for distillate oil and natural gas firing. Natural gas is presently the primary fuel.

2. HEATING PLANT UNITS

Heating Plant No. 260

2 × 28.5 MBtu/h; Cleaver Brooks (1975)
4 × 33.5 MBtu/h; Union Iron Works (1955)
2 × 33.5 MBtu/h; Erie City (1962)

Heating Plant No. 825

3 × 40.2 MBtu/h; Murray Iron (1957)

3. IDEAL CAPACITY FACTOR ANALYSIS

Plant No. 260		Plant No. 825	
Boiler output (MBtu/h)	FY 1985 Ideal capacity factor	Boiler output (MBtu/h)	FY 1985 Ideal capacity factor
30	0.83	20	0.58
50	0.77	30	0.58
70	0.72	40	0.56
90	0.68	50	0.53
120	0.64	60	0.51
150	0.60	70	0.48
180	0.52	80	0.43
210	0.44		

4. ENERGY PRICES

FY 1986 Price Data

Electricity = 5.2¢/kWh
Distillate oil = $5.92/MBtu
Natural gas = $2.85/MBtu

C. H. Guernsey & Co. Survey

Electricity = no reported value
Distillate oil = $5.63/MBtu
Natural gas = $2.97/MBtu

5. OTHER CONSIDERATIONS

A study could be conducted to investigate the feasibility of replacing some of the smaller steam plants with a more efficient steam distribution system. Air-quality constraints appear to be strict.

6. COAL CONVERSION PROJECT OUTLOOK

The most feasible project for plant No. 260 would involve refit/replacement of one to three of the 33.5-MBtu/h boilers. Low gas prices will probably prevent any coal conversion project from being economical at this time.

An overall load factor of about 65% is estimated for refit/replacement of two 33.5-MBtu/h units. Replacing a single 33.5-MBtu/h unit would probably result in a load factor of about 72%. If three 33.5-MBtu/h units are replaced, the expected load factor decreases to about 57%.

A coal conversion project could be considered for heating plant No. 825, but it appears to be considerably less attractive. If one 40.2-MBtu/h unit were replaced or converted to utilize coal, the expected overall load factor would optimistically be 46%.

Table A.4. Hill AFB (Bldg.260): 1 x 33.5 MBtu/h, without SO_2 control

Total steam/hot water output	= 33.5 MBtu/h
Boiler capacity factor	= 0.720
Number of units for refit	= 1
Hydrated lime price($/ton)	= 40.00
Ash disposal price ($/ton)	= 10.00
Electric price (cents/kWh)	= 5.20
Labor rate (k$/year)	= 35.00
Limestone price ($/ton)	= 20.00
FUEL PRICES	
Natural gas price ($/MBtu)	= 2.97
#2 Oil price ($/MBtu)	= 0.00
#6 Oil price ($/MBtu)	= 0.00
OPTIONS	
Soot blower multiplier	= 1.0
Tube bank mod multiplier	= 1.0
Bottom ash pit multiplier	= 1.0
SO_2 control multiplier	= 0.0
LIMESTONE/LIME	
Inert fraction	= 0.05
ECONOMIC PARAMETERS	
Project life (year)	= 30
Discount rate (%/year)	= 10
Uniform pres worth factor	= 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction =	0.100	0.090
Sulfur fraction =	0.025	0.022
HHV (Btu/lb) =	12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu)	= 1.50
Stoker coal ($/MBtu)	= 1.75
Coal/H_2O mix ($/MBtu)	= 3.00
Coal/oil mix ($/MBtu)	= 3.50

Primary fuel is 3
NATURAL GAS
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest-ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	2.97	0.0	540.0	784.4	12485.3	<-- Primary fuel	
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	1	0.800	1.50	2155.9	863.1	396.2	14027.4	0.890	11,005
Slagging burner refit	1	0.800	1.50	3596.4	863.1	396.2	15467.9	0.807	11,005
Modular FBC refit	1	0.790	1.50	4107.3	835.9	401.2	15769.2	0.792	11,144
Stoker firing refit	No applicable because existing boiler was designed for #2 oil								
Coal/water slurry	1	0.750	3.00	2156.7	765.0	845.2	17335.9	0.720	11,738
Coal/oil slurry	1	0.780	3.50	1792.0	682.7	948.1	17165.2	0.727	5,079
Low Btu gasifier refit	1	0.679	1.75	3203.3	895.9	544.9	16785.0	0.744	12,455
Packaged shell stoker	1	0.760	1.75	2777.9	828.4	486.5	15173.9	0.823	11,121
Packaged shell FBC	1	0.760	1.50	3439.8	836.3	417.0	15255.1	0.818	11,584
Field erected stoker	1	0.800	1.75	4905.1	821.1	462.2	17002.6	0.734	10,565
Field erected FBC	1	0.800	1.50	5360.4	882.8	396.2	17417.6	0.717	11,005
Pulverized coal boiler	1	0.820	1.50	5695.3	913.7	386.5	17952.4	0.695	10,736
Circulating FBC	1	0.810	1.50	6267.7	881.2	391.3	18263.4	0.684	10,869

Table A.5. Hill AFB (Bldg. 260): 2 x 33.5 MBtu/h, without SO_2 control

Total steam/hot water output	= 67.0 MBtu/h
Boiler capacity factor	= 0.650
Number of units for refit	= 2
Hydrated lime price($/ton)	= 40.00
Ash disposal price ($/ton)	= 10.00
Electric price (cents/kWh)	= 5.20
Labor rate (k$/year)	= 35.00
Limestone price ($/ton)	= 20.00
FUEL PRICES	
Natural gas price ($/MBtu)	= 2.97
#2 Oil price ($/MBtu)	= 0.00
#6 Oil price ($/MBtu)	= 0.00
OPTIONS	
Soot blower multiplier	= 1.0
Tube bank mod multiplier	= 1.0
Bottom ash pit multiplier	= 1.0
SO_2 control multiplier	= 0.0
LIMESTONE/LIME	
Inert fraction	= 0.05
ECONOMIC PARAMETERS	
Project life (year)	= 30
Discount rate (%/year)	= 10
Uniform pres worth factor	= 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction =	0.100	0.090
Sulfur fraction =	0.025	0.022
HHV (Btu/lb) =	12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu)	= 1.50
Stoker coal ($/MBtu)	= 1.75
Coal/H_2O mix ($/MBtu)	= 3.00
Coal/oil mix ($/MBtu)	= 3.50

Primary fuel is 3
NATURAL GAS
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest-ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	2.97	0.0	685.5	1416.3	19813.2	<-- Primary fuel	
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	2	0.800	1.50	3988.5	1172.7	715.3	21786.5	0.909	19,870
Slagging burner refit	2	0.800	1.50	6653.4	1172.7	715.3	24451.5	0.810	19,870
Modular FBC refit	2	0.790	1.50	7598.5	1124.5	724.4	25027.4	0.792	20,121
Stoker firing refit	Not applicable because existing boilers were designed for #2 oil								
Coal/water slurry	2	0.750	3.00	3989.9	1028.2	1526.0	28068.0	0.706	21,194
Coal/oil slurry	2	0.780	3.50	3315.1	918.4	1711.9	28110.6	0.705	9,171
Low Btu gasifier refit	2	0.679	1.75	5926.1	1252.9	983.8	27011.3	0.734	22,487
Packaged shell stoker	2	0.760	1.75	5139.0	1111.0	878.4	23893.5	0.829	20,079
Packaged shell FBC	2	0.760	1.50	6363.6	1125.3	753.0	24069.6	0.823	20,915
Field erected stoker	1	0.800	1.75	7469.9	1007.5	834.5	24834.3	0.798	19,075
Field erected FBC	1	0.800	1.50	8227.7	1093.9	715.3	25283.4	0.784	19,870
Pulverized coal boiler	1	0.820	1.50	8707.6	1125.6	697.9	25896.9	0.765	19,385
Circulating FBC	1	0.810	1.50	9889.7	1094.2	706.5	26864.8	0.738	19,624

Table A.6. Hill AFB (Bldg.260): 3 x 33.5 MBtu/h, without SO_2 control

Total steam/hot water output = 100.5 MBtu/h
Boiler capacity factor = 0.570
Number of units for refit = 3
Hydrated lime price($/ton) = 40.00
Ash disposal price ($/ton) = 10.00
Electric price (cents/kWh) = 5.20
Labor rate (k$/year) = 35.00
Limestone price ($/ton) = 20.00

FUEL PRICES

Natural gas price ($/MBtu) = 2.97
#2 Oil price ($/MBtu) = 0.00
#6 Oil price ($/MBtu) = 0.00

OPTIONS

Soot blower multiplier = 1.0
Tube bank mod multiplier = 1.0
Bottom ash pit multiplier = 1.0
SO_2 control multiplier = 0.0

LIMESTONE/LIME

Inert fraction = 0.05

ECONOMIC PARAMETERS

Project life (year) = 30
Discount rate (%/year) = 10
Uniform pres worth factor = 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction =	0.100	0.090
Sulfur fraction =	0.025	0.022
HHV (Btu/lb) =	12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu) = 1.50
Stoker coal ($/MBtu) = 1.75
Coal/H_2O mix ($/MBtu) = 3.00
Coal/oil mix ($/MBtu) = 3.50

Primary fuel is 3
NATURAL GAS
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest-ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	2.97	0.0	793.3	1863.0	25040.8	<-- Primary fuel	
#2 Oil fired boiler	-	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	3	0.800	1.50	5821.0	1402.9	940.9	27916.0	0.897	26,136
Slagging burner refit	3	0.800	1.50	9710.4	1402.9	940.9	31805.4	0.787	26,136
Modular FBC refit	3	0.790	1.50	11089.6	1337.8	952.8	32682.7	0.766	26,467
Stoker firing refit	Not applicable because existing boilers were designed for #2 oil								
Coal/water slurry	3	0.750	3.00	5823.0	1223.1	2007.3	36275.1	0.690	27,879
Coal/oil slurry	3	0.780	3.50	4838.3	1093.7	2251.7	36375.9	0.688	12,063
Low Btu gasifier refit	3	0.679	1.75	8648.9	1527.0	1294.1	35243.4	0.711	29,580
Packaged shell stoker	3	0.760	1.75	7500.2	1320.0	1155.5	30836.8	0.812	26,411
Packaged shell FBC	3	0.760	1.50	9287.4	1338.8	990.4	31244.8	0.801	27,512
Field erected stoker	1	0.800	1.75	9593.1	1140.7	1097.7	30694.2	0.816	25,091
Field erected FBC	1	0.800	1.50	10612.4	1245.4	940.9	31222.4	0.802	26,136
Pulverized coal boiler	1	0.820	1.50	11202.9	1276.6	918.0	31890.7	0.785	25,499
Circulating FBC	1	0.810	1.50	12969.7	1246.0	929.3	33475.8	0.748	25,814

Table A.7. Hill AFB (Bldg. 825): 1 x 40 MBtu/h, without SO_2 control

Total steam/hot water output = 40.0 MBtu/h
Boiler capacity factor = 0.460
Number of units for refit = 1
Hydrated lime price($/ton) = 40.00
Ash disposal price ($/ton) = 10.00
Electric price (cents/kWh) = 5.20
Labor rate (k$/year) = 35.00
Limestone price ($/ton) = 20.00

FUEL PRICES

Natural gas price ($/MBtu) = 2.97
#2 Oil price ($/MBtu) = 0.00
#6 Oil price ($/MBtu) = 0.00

OPTIONS

Soot blower multiplier = 1.0
Tube bank mod multiplier = 1.0
Bottom ash pit multiplier = 1.0
SO_2 control multiplier = 0.0

LIMESTONE/LIME

Inert fraction = 0.05

ECONOMIC PARAMETERS

Project life (year) = 30
Discount rate (%/year) = 10
Uniform pres worth factor = 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction =	0.100	0.090
Sulfur fraction =	0.025	0.022
HHV (Btu/lb) =	12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu) = 1.50
Stoker coal ($/MBtu) = 1.75
Coal/H_2O mix ($/MBtu) = 3.00
Coal/oil mix ($/MBtu) = 3.50

Primary fuel is 3
NATURAL GAS
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest- ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	2.97	0.0	565.3	598.4	10970.2	<-- Primary fuel	
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	1	0.800	1.50	2366.9	890.6	302.2	13611.8	0.806	8,395
Slagging burner refit	1	0.800	1.50	3962.6	890.6	302.2	15207.6	0.721	8,395
Modular FBC refit	1	0.790	1.50	4528.3	865.5	306.0	15572.7	0.704	8,501
Stoker firing refit	Not applicable because existing boiler was designed for #2 oil								
Coal/water slurry	1	0.750	3.00	2380.0	793.9	644.7	15942.1	0.688	8,955
Coal/oil slurry	1	0.780	3.50	1981.5	708.7	723.3	15480.5	0.709	3,875
Low Btu gasifier refit	1	0.679	1.75	3546.1	922.8	415.7	16164.0	0.679	9,501
Packaged shell stoker	1	0.760	1.75	3050.0	859.8	371.1	14654.5	0.749	8,483
Packaged shell FBC	1	0.760	1.50	3825.0	865.9	318.1	14986.5	0.732	8,837
Field erected stoker	1	0.800	1.75	5457.7	852.7	352.6	16819.4	0.652	8,059
Field erected FBC	1	0.800	1.50	5976.5	915.6	302.2	17457.0	0.628	8,395
Pulverized coal boiler	1	0.820	1.50	6343.9	947.9	294.8	18059.5	0.607	8,190
Circulating FBC	1	0.810	1.50	7036.9	907.2	298.5	18403.2	0.596	8,291

KELLY AFB: AFLC

1. BACKGROUND

Kelly AFB is located near San Antonio, Texas. The central heating plant (Bldg. 376) has five water-tube boilers that burn natural gas or No. 2 oil as the backup fuel; 125 psi steam is produced. The average fuel use is ~65 MBtu/h. Boiler efficiency is 79 to 82%. No boilers were designed for coal. All other boiler plants at Kelly are too small for consideration.

2. HEATING PLANT UNITS

Heating Plant No. 376

2 × 54.5 MBtu/h; Babcock & Wilcox (1971)
49.6 MBtu/h; Babcock & Wilcox (1976)
2 × 50 MBtu/h; Vogt (1954)

3. IDEAL CAPACITY FACTOR ANALYSIS

Plant No. 376

Steam output (MBtu/h)	FY 1985 Ideal capacity factor
30	0.99
40	0.95
50	0.86
60	0.76
70	0.67
80	0.60

4. ENERGY PRICES

FY 1986 Price Data

Electricity = 5.2¢/kWh
Natural gas = $3.88/MBtu

C. H. Guernsey & Co. Survey

Electricity = 5.1¢/kWh
Natural gas = $4.0/MBtu
Distillate oil = $5.88/MBtu

5. COAL CONVERSION PROJECT OUTLOOK

The most likely projects would include refit/replacement of one or two boiler units. Existing boilers were probably designed for distillate oil and natural gas, which may make it difficult to refit an existing boiler for coal firing.

If one of the 54.5-MBtu/h units were converted to (or replaced with) coal, the maximum capacity factor based on monthly data would be roughly 82%. If equipment availability is assumed to be 90%, then a realistic load factor would be somewhere near 70%. A project that involved converting or replacing two units would have a load factor near 45%.

Table A.8. Kelly AFB: 1 x 50 MBtu/h, without SO_2 control

Total steam/hot water output	= 50.0 MBtu/h
Boiler capacity factor	= 0.750
Number of units for refit	= 1
Hydrated lime price($/ton)	= 40.00
Ash disposal price ($/ton)	= 10.00
Electric price (cents/kWh)	= 5.10
Labor rate (k$/year)	= 35.00
Limestone price ($/ton)	= 20.00
FUEL PRICES	
Natural gas price ($/MBtu)	= 4.00
#2 Oil price ($/MBtu)	= 0.00
#6 Oil price ($/MBtu)	= 0.00
OPTIONS	
Soot blower multiplier	= 1.0
Tube bank mod multiplier	= 1.0
Bottom ash pit multiplier	= 1.0
SO_2 control multiplier	= 0.0
LIMESTONE/LIME	
Inert fraction	= 0.05
ECONOMIC PARAMETERS	
Project life (year)	= 30
Discount rate (%/year)	10
Uniform pres worth factor	= 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction	= 0.100	0.090
Sulfur fraction	= 0.025	0.022
HHV (Btu/lb)	= 12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu)	= 1.50
Stoker coal ($/MBtu)	= 1.75
Coal/H_2O mix ($/MBtu)	= 3.00
Coal/oil mix ($/MBtu)	= 3.50

Primary fuel is 3
NATURAL GAS
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest-ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	4.00	0.0	620.0	1642.5	21328.8	<-- Primary fuel	
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	1	0.800	1.50	2665.3	982.8	615.9	17736.1	1.203	17,109
Slagging burner refit	1	0.800	1.50	4481.1	982.8	615.9	19551.9	1.091	17,109
Modular FBC refit	1	0.790	1.50	5124.4	947.1	623.7	19932.5	1.070	17,326
Stoker firing refit	Not applicable because existing boiler was designed for #2 oil								
Coal/water slurry	1	0.750	3.00	2696.7	868.4	1314.0	23269.9	0.917	18,250
Coal/oil slurry	1	0.780	3.50	2251.2	771.9	1474.0	23423.5	0.911	7,897
Low Btu gasifier refit	1	0.679	1.75	4034.2	1044.3	847.1	21864.7	0.975	19,363
Packaged shell stoker	1	0.760	1.75	3434.5	935.7	756.4	19385.9	1.100	17,289
Packaged shell FBC	1	0.760	1.50	4376.8	947.8	648.4	19423.5	1.098	18,010
Field erected stoker	1	0.800	1.75	6247.5	925.3	718.6	21744.1	0.981	16,425
Field erected FBC	1	0.800	1.50	6858.9	1001.3	615.9	22104.2	0.965	17,109
Pulverized coal boiler	1	0.820	1.50	7271.5	1032.6	600.9	22670.4	0.941	16,692
Circulating FBC	1	0.810	1.50	8147.7	1002.4	608.3	23332.1	0.914	16,898

McCLELLAN AFB: AFLC

1. BACKGROUND

McClellan AFB is located near Sacramento, California. There are three steam plants at the base, but only one (Bldg. 367) is large enough for potential coal use. The average load appears to be ~29 MBtu/h. No boilers were designed for coal; all are water-tube units producing 125 psi, 353°F steam. Natural gas is the primary fuel, with No. 5 oil as backup. The average fuel consumption for the entire base is about 60 MBtu/h.

2. HEATING PLANT UNITS

Heating Plant No. 367

2 × 50 MBtu/h; Nebraska Boiler (1979)
19 MBtu/h; Babcock & Wilcox (1942)
25 MBtu/h; Babcock & Wilcox (1920)

The Babcock & Wilcox (B&W) units are not listed in the 1986 information and may be retired.

3. IDEAL CAPACITY FACTOR ANALYSIS

Plant No. 367

Steam output (MBtu/h)	FY 1985 Ideal capacity factor
20	0.85
30	0.72
40	0.65
50	0.57
60	0.49
70	0.42

4. ENERGY PRICES

FY 1986 Price Data

	Year Average	End of Year
Distillate oil	= $5.76/MBtu	
Natural gas	= $3.92/MBtu	$3.30/MBtu
Electricity	= $10.2/MBtu = 3.5¢/kWh	Same

C. H. Guernsey & Co. Survey

No data were available.

5. OTHER CONSIDERATIONS

McClellan AFB is located in a nonattainment area; strict air requirements would apply, and emission offsets may be necessary.

6. COAL CONVERSION PROJECT OUTLOOK

The small size of the main steam plant and the strict pollution controls probably make McClellan an unattractive base for coal utilization. A possible project would be conversion or replacement of a 50-MBtu/h boiler with coal-burning equipment, with an expected load factor near 50%.

Table A.9. McClellan AFB: 1 x 50 MBtu/h, without SO_2 control

Total steam/hot water output = 50.0 MBtu/h
Boiler capacity factor = 0.500
Number of units for refit = 1
Hydrated lime price($/ton) = 40.00
Ash disposal price ($/ton) = 10.00
Electric price (cents/kWh) = 3.50
Labor rate (k$/year) = 35.00
Limestone price ($/ton) = 20.00

FUEL PRICES

Natural gas price ($/MBtu) = 3.92
#2 Oil price ($/MBtu) = 0.00
#6 Oil price ($/MBtu) = 0.00

OPTIONS

Soot blower multiplier = 0.0
Tube bank mod multiplier = 1.0
Bottom ash pit multiplier = 1.0
SO_2 control multiplier = 0.0

LIMESTONE/LIME

Inert fraction = 0.05

ECONOMIC PARAMETERS

Project life (year) = 30
Discount rate (%/year) = 10
Uniform pres worth factor = 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction =	0.100	0.[illegible]0
Sulfur fraction =	0.025	0.022
HHV (Btu/lb) =	12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu) = 1.50
Stoker coal ($/MBtu) = 1.75
Coal/H_2O mix ($/MBtu) = 3.00
Coal/oil mix ($/MBtu) = 3.50

Primary fuel is 3
NATURAL GAS
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest- ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	3.92	0.0	599.4	1073.1	15766.4	<-- Primary fuel	
#2 Oil fired boiler	-	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired toiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	1	0.800	1.50	2482.6	935.2	410.6	15169.4	1.039	11,406
Slagging burner refit	1	0.800	1.50	4298.4	935.2	410.6	16985.2	0.928	11,406
Modular FBC refit	1	0.790	1.50	4941.7	909.7	415.8	17437.0	0.904	11,551
Stoker firing refit	Not applicable because existing boiler was designed for #6 oil								
Coal/water slurry	1	0.750	3.00	2514.0	835.9	876.0	18651.8	0.845	12,167
Coal/oil slurry	1	0.780	3.50	2068.5	742.8	982.7	18335.0	0.860	5,264
Low Btu gasifier refit	1	0.679	1.75	4034.2	954.3	564.8	18354.1	0.859	12,909
Packaged shell stoker	1	0.760	1.75	3434.5	904.1	504.3	16711.0	0.943	11,526
Packaged shell FBC	1	0.760	1.50	4376.8	910.1	432.2	17031.2	0.926	12,007
Field erected stoker	1	0.800	1.75	6247.5	897.2	479.1	19221.7	0.820	10,950
Field erected FBC	1	0.800	1.50	6858.9	963.9	410.6	19816.6	0.796	11,406
Pulverized coal boiler	1	0.820	1.50	7271.5	998.5	400.6	20460.4	0.771	11,128
Circulating FBC	1	0.810	1.50	8147.7	951.8	405.6	20943.9	0.753	11,265

ROBINS AFB: AFLC

1. BACKGROUND

Robins AFB is located near Warner Robins, Georgia. There are two major heating plants on the base, but only the larger plant (Bldg. 177) should be considered for conversion.

2. HEATING PLANT UNITS

Heating Plant No. 177

2 × 98 MBtu/h; Erie City (1966)
2 × 54 MBtu/h; Babcock & Wilcox (1953)
54 MBtu/h; Wickes (1954)
5 MBtu/h; Superior (1977) (oil only)

Heat Plant No. 644

24 MBtu/h; Erie City (1966)
2 × 24 MBtu/h; Trane (197[illegible])
21 MBtu/h; Babcock & Wilcox (1955)

The B&W and Wicks units were originally designed for coal. The coal-burning boilers were converted in 1967 to burn natural gas, with distillate oil as backup. Heating plant No. 177 produces 125 psi steam; boiler efficiencies range from about 69% at low loads to 78% at full load. No coal-handling equipment remains at the site.

3. IDEAL CAPACITY FACTOR ANALYSIS

Plant No. 177

Steam output (MBtu/h)	FY 1985 Ideal capacity factor
30	0.83
50	0.83
70	0.78
90	0.70
120	0.59
150	0.49

4. ENERGY PRICES

FY 1986 Price Data

	Year Average	End of Year
Distillate oil	= $5.50/MBtu	$5.90/MBtu
Natural gas	= $3.90/MBtu	$3.90/MBtu
Electricity	= $12.96/MBtu = 4.4¢/kWh	4.4¢/kWh

C. H. Guernsey & Co. Survey

Electricity = 4.5¢/kWh
Natural gas = $3.2/MBtu
Distillate oil = $5.43/MBtu

5. COAL CONVERSION PROJECT OUTLOOK

The most probable project would be to refit/replace one or two of the coal-designed 54-MBtu/h boiler units in plant No. 177. The capacity factor (based on monthly data for plant No. 177) for a project involving an output of 108 MBtu/h steam capacity would be ~60%. Assuming ~90% equipment availability would give an overall capacity factor of 55%. If only a single 54-MBtu/h unit were involved in a project, an overall capacity factor of ~72% would be expected.

Table A.10. Robins AFB: 1 x 54 MBtu/h, without SO_2 control

Total steam/hot water output = 54.0 MBtu/h
Boiler capacity factor = 0.720
Number of units for refit = 1
Hydrated lime price($/ton) = 40.00
Ash disposal price ($/ton) = 10.00
Electric price (cents/kWh) = 4.40
Labor rate (k$/year) = 35.00
Limestone price ($/ton) = 20.00

FUEL PRICES

Natural gas price ($/MBtu) = 3.90
#2 Oil price ($/MBtu) = 0.00
#6 Oil price ($/MBtu) = 0.00

OPTIONS

Soot blower multiplier = 0.0
Tube bank mod multiplier = 0.0
Bottom ash pit multiplier = 1.0
SO_2 control multiplier - 0.0

LIMESTONE/LIME

Inert fraction = 0.05

ECONOMIC PARAMETERS

Project life (year) = 30
Discount rate (%/year) = 10
Uniform pres worth factor = 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction =	0.100	0.090
Sulfur fraction =	0.025	0.022
HHV (Btu/lb) =	12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu) = 1.50
Stoker coal ($/MBtu) = 1.75
Coal/H_2O mix ($/MBtu) = 3.00
Coal/oil mix ($/MBtu) = 3.50

Primary fuel is 3
NATURAL GAS
1-#6 Oil, 2-#2 Oil, 3 NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	3.90	0.0	629.6	1660.4	21587.0	<-- Primary fuel	
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	-	0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	1	0.800	1.50	2586.3	992.3	638.6	17960.7	1.202	17,739
Slagging burner refit	1	0.800	1.50	4485.0	992.3	638.6	19859.5	1.087	17,739
Modular FBC refit	1	0.790	1.50	5157.5	958.1	646.7	20286.0	1.064	17,964
Stoker firing refit	1	0.760	1.75	3062.4	947.7	784.3	19389.1	1.113	17,926
Coal/water slurry	1	0.750	3.00	2325.9	879.5	1362.4	23459.6	0.920	18,322
Coal/oil slurry	1	0.780	3.50	2066.0	780.4	1528.3	23830.2	0.906	8,187
Low Btu gasifier refit	1	0.679	1.75	4218.8	1043.9	878.3	22339.6	0.966	20,076
Packaged shell stoker	2	0.760	1.75	4591.5	1034.9	784.3	21740.8	0.993	17,926
Packaged shell FBC	2	0.760	1.50	5598.9	1046.1	672.2	21797.4	0.990	18,673
Field erected stoker	1	0.800	1.75	6547.1	937.8	745.0	22411.4	0.963	17,029
Field erected FBC	1	0.800	1.50	7194.0	1013.8	638.6	22771.3	0.948	17,739
Pulverized coal boiler	1	0.820	1.50	7623.4	1046.4	623.0	23360.5	0.924	17,306
Circulating FBC	1	0.810	1.50	8572.2	1011.3	630.7	24051.4	0.898	17,520

Table A.11. Robins AFB: 2 x 54 MBtu/h, without SO_2 control

Total steam/hot water output = 108.0 MBtu/h
Boiler capacity factor = 0.550
Number of units for refit = 2
Hydrated lime price($/ton) = 40.00
Ash disposal price ($/ton) = 10.00
Electric price (cents/kWh) = 4.40
Labor rate (k$/year) = 35.00
Limestone price ($/ton) = 20.00

FUEL PRICES

Natural gas price ($/MBtu) = 3.90
#2 Oil price ($/MBtu) = 0.00
#6 Oil price ($/MBtu) = 0.00

OPTIONS

Soot blower multiplier = 0.0
Tube bank mod multiplier = 0.0
Bottom ash pit multiplier = 1.0
SO_2 control multiplier = 0.0

LIMESTONE/LIME

Inert fraction = 0.05

ECONOMIC PARAMETERS

Project life (year) = 30
Discount rate (%/year) = 10
Uniform pres worth factor = 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction =	0.100	0.090
Sulfur fraction =	0.025	0.022
HHV (Btu/lb) =	12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu) = 1.50
Stoker coal ($/MBtu) = 1.75
Coal/H_2O mix ($/MBtu) = 3.00
Coal/oil mix ($/MBtu) = 3.50

Primary fuel is 3
NATURAL GAS
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest-ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	3.90	0.0	801.6	2536.7	31469.4	<-- Primary fuel	
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	2	0.800	1.50	4784.7	1337.3	975.6	26588.8	1.184	27,101
Slagging burner refit	2	0.800	1.50	8297.3	1337.3	975.6	30101.5	1.045	27,101
Modular FBC refit	2	0.790	1.50	9541.4	1281.4	988.0	30935.0	1.017	27,444
Stoker firing refit	2	0.760	1.75	5665.5	1265.4	1198.2	28889.7	1.089	27,387
Coal/water slurry	2	0.750	3.00	4303.0	1176.1	2081.4	35010.5	0.899	28,908
Coal/oil slurry	2	0.780	3.50	3822.1	1045.7	2334.9	35690.3	0.882	12,508
Low Btu gasifier refit	2	0.679	1.75	7804.7	1446.6	1341.9	34091.4	0.923	30,672
Packaged shell stoker	3	0.760	1.75	7789.4	1330.7	1198.2	31628.4	0.995	27,387
Packaged shell FBC	3	0.760	1.50	9695.3	1347.7	1027.0	32081.6	0.981	28,528
Field erected stoker	1	0.800	1.75	10031.8	1150.5	1138.3	31607.7	0.996	26,017
Field erected FBC	1	0.800	1.50	11106.0	1254.0	975.6	32124.6	0.980	27,101
Pulverized coal boiler	1	0.820	1.50	11718.6	1287.2	951.8	32825.6	0.959	26,440
Circulating FBC	1	0.810	1.50	13613.5	1248.8	963.6	34469.3	0.913	26,767

Table A.12. Robins AFB: 1 x 98 MBtu/h, without SO_2 control

Tota' steam/hot water output = 98.0 MBtu/h			
Boiler capacity factor = 0.580			
Number of units for refit = 1			
Hydrated lime price($/ton) = 40.00	COAL PROPERTIES		
Ash disposal price ($/ton) = 10.00		R.O.M.	Stoker
Electric price (cents/kWh) = 4.40	Ash fraction =	0.100	0.090
Labor rate (k$/year) = 35.00	Sulfur fraction =	0.025	0.022
Limestone price ($/ton) = 20.00	HHV (Btu/lb) =	12000	12500
FUEL PRICES	FUEL PRICES		
Natural gas price ($/MBtu) = 3.90	R.O.M. coal ($/MBtu) =	1.50	
#2 Oil price ($/MBtu) = 0.00	Stoker coal ($/MBtu) =	1.75	
#6 Oil price ($/MBtu) = 0.00	Coal/H_2O mix ($/MBtu) =	3.00	
OPTIONS	Coal/oil mix ($/MBtu) =	3.50	
Soot blower multiplier = 1.0			
Tube bank mod .ultiplier = 1.0	Primary fuel is 3		
Bottom ash pit multiplier = 1.0	NATURAL GAS		
SO_2 control multiplier = 0.0	1=#6 Oil, 2=#2 Oil, 3=NG		
LIMESTONE/LIME			
Inert fraction = 0.05			
ECONOMIC PARAMETERS			
Project life (year) = 30			
Discount rate (%/year) = 10			
Uniform pres worth factor = 9.427			

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest-ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	3.90	0.0	774.5	2427.4	30184.0	<-- Primary fuel	
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	1	0.800	1.50	3847.4	1196.0	933.6	23922.9	1.262	25,933
Slagging burner refit	1	0.800	1.50	6535.4	1196.0	933.6	26610.9	1.134	25,933
Modular FBC refit	1	0.790	1.50	7484.5	1148.3	945.4	27221.8	1.109	26,262
Stoker firing refit	Not appliable because boiler was designed for #2 oil								
Coal/water slurry	1	0.750	3.00	3957.8	1058.1	1991.7	32707.5	0.923	27,662
Coal/oil slurry	1	0.780	3.50	3332.0	935.2	2234.2	33210.0	0.909	11,969
Low Btu gasifier refit	2	0.679	1.75	7376.3	1397.4	1284.1	32654.3	0.924	29,350
Packaged shell stoker	2	0.760	1.75	6285.6	1230.2	1146.5	28690.3	1.052	26,206
Packaged shell FBC	2	0.760	1.50	7998.4	1246.5	982.7	29013.1	1.040	27,298
Field erected stoker	1	0.800	1.75	9444.3	1117.9	1089.2	30250.7	0.998	24,896
Field erected FBC	1	0.800	1.50	10445.0	1217.3	933.6	30721.1	0.983	25,933
Pulverized coal boiler	1	0.820	1.50	11028.1	1250.4	910.8	31401.9	0.961	25,301
Circulating FBC	1	0.810	1.50	12752.0	1213.0	922.1	32879.0	0.918	25,613

TINKER AFB: AFLC

1. BACKGROUND

Tinker AFB is near Oklahoma City, Oklahoma. The available information for Tinker is relatively poor, partially because it was not considered in the C. H. Guernsey & Co. survey. There are two boiler plants at Tinker AFB that are large enough for some consideration in this study. The heating plant in Bldg. 3001 is the largest of the these, with an average fuel use of roughly 150 MBtu/h. The heating plant in Bldg. 208 appears to have a year-round average fuel use of about 75 MBtu/h. Natural gas firing is used with distillate oil as the secondary fuel. No boilers at the base were designed for coal burning.

2. HEATING PLANT UNITS

Heating Plant No. 3001

3 × 97 MBtu/h; Riley Stoker (1942)

Heating Plant No. 208

4 × 41 MBtu/h; Wickes (1942)

3. IDEAL CAPACITY FACTOR ANALYSIS

No monthly data are currently available.

4. ENERGY PRICES

FY 1986 Price Data

Electricity = $14/MBtu = 4.8¢/kWh
Natural gas = $2.85/MBtu

Gas prices declined during FY 1986 and apparently were ~$2.0/MBtu in the latter portion of the year.

5. OTHER CONSIDERATIONS

The boilers in plant No. 3001 were scheduled for upgrading in 1982.

6. COAL CONVERSION PROJECT OUTLOOK

Tinker AFB may be a poor candidate for coal conversion, according to AFLC sources. Tinker does seem to be a large fuel user, however, and it is not clear what would make it a poor candidate. Low gas prices probably make coal unattractive at this time.

A likely project would be to refit or replace one or two of the 97-MBtu/h units in plant No. 3001. If one 97-MBtu/h unit burned coal, an overall capacity factor of about 85% would be expected, and if two units burned coal a 60% capacity factor might be expected.

A likely project for boiler plant No. 208 would be to refit or replace a 41-MBtu/h boiler. An overall capacity factor near 80% might be expected for this scenario.

The estimates for capacity factor are based on load data from other Air Force heating plants of similar size.

Table A.13. Tinker AFB (Bldg. 3001): 1 x 97 MBtu/h, without SO_2 control

Total steam/hot water output = 97.0 MBtu/h
Boiler capacity factor = 0.850
Number of units for refit = 1
Hydrated lime price($/ton) = 40.00
Ash disposal price ($/ton) = 10.00
Electric price (cents/kWh) = 4.80
Labor rate (k$/year) = 35.00
Limestone price ($/ton) = 20.00

FUEL PRICES

Natural gas price ($/MBtu) = 2.85
#2 Oil price ($/MBtu) = 0.00
#6 Oil price ($/MBtu) = 0.00

OPTIONS

Soot blower multiplier = 1.0
Tube bank mod multiplier = 1.0
Bottom ash pit multiplier = 1.0
SO_2 control multiplier = 0.0

LIMESTONE/LIME

Inert fraction = 0.05

ECONOMIC PARAMETERS

Project life (year) = 30
Discount rate (%/year) = 10
Uniform pres worth factor = 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction =	0.100	0.090
Sulfur fraction =	0.025	0.022
HHV (Btu/lb) =	12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu) = 1.50
Stoker coal ($/MBtu) = 1.75
Coal/H_2O mix ($/MBtu) = 3.00
Coal/oil mix ($/MBtu) = 3.50

Primary fuel is 3
NATURAL GAS
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest- ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	2.85	0.0	796.2	2573.1	31761.9	<-- Primary fuel	
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	1	0.800	1.50	3825.5	1255.0	1354.2	28422.4	1.117	37,618
Slagging burner refit	1	0.800	1.50	6497.4	1255.0	1354.2	31094.3	1.021	37,618
Modular FBC refit	1	0.790	1.50	7440.9	1193.2	1371.4	31616.7	1.005	38,094
Stoker firing refit	Not applicable because boiler was designed for #2 oil								
Coal/water slurry	1	0.750	3.00	3934.4	1096.4	2889.0	41504.6	0.765	40,126
Coal/oil slurry	1	0.780	3.50	3311.9	966.8	3240.9	42977.4	0.739	17,362
Low Btu gasifier refit	2	0.679	1.75	7332.5	1497.0	1862.6	39003.0	0.814	42,574
Packaged shell stoker	2	0.760	1.75	6251.2	1266.3	1663.1	33866.4	0.938	38,014
Packaged shell FBC	2	0.760	1.50	7948.9	1291.6	1425.5	33563.3	0.946	39,598
Field erected stoker	1	0.800	1.75	9384.5	1150.2	1579.9	35121.1	0.904	36,113
Field erected FBC	1	0.800	1.50	10377.7	1261.7	1354.2	35038.3	0.906	37,618
Pulverized coal boiler	1	0.820	1.50	10957.7	1291.2	1321.2	35585.1	0.893	36,700
Circulating FBC	1	0.810	1.50	12664.4	1277.3	1337.5	37313.7	0.851	37,153

Table A.14. Tinker AFB (Bldg. 208): 1 x 41 MBtu/h, without SO_2 control

Total steam/hot water output	= 41.0 MBtu/h
Boiler capacity factor	= 0.800
Number of units for refit	= 1
Hydrated lime price($/ton)	= 40.00
Ash disposal price ($/ton)	= 10.00
Electric price (cents/kWh)	= 4.80
Labor rate (k$/year)	= 35.00
Limestone price ($/ton)	= 20.00
FUEL PRICES	
Natural gas price ($/MBtu)	= 2.85
#2 Oil price ($/MBtu)	= 0.00
#6 Oil price ($/MBtu)	= 0.00
OPTIONS	
Soot blower multiplier	= 1.0
Tube bank mod multiplier	= 1.0
Bottom ash pit multiplier	= 1.0
SO_2 control multiplier	= 0.0
LIMESTONE/LIME	
Inert fraction	= 0.05
ECONOMIC PARAMETERS	
Project life (year)	= 30
Discount rate (%/year)	= 10
Uniform pres worth factor	= 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction	= 0.100	0.090
Sulfur fraction	= 0.025	0.022
HHV (Btu/lb)	= 12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu)	= 1.50
Stoker coal ($/MBtu)	= 1.75
Coal/H_2O mix ($/MBtu)	= 3.00
Coal/oil mix ($/MBtu)	= 3.50

Primary fuel is 3
NATURAL GAS
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest-ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	2.85	0.0	577.8	1023.6	15096.6	<-- Primary fuel	
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	1	0.800	1.50	2398.0	920.7	538.7	16156.1	0.934	14,965
Slagging burner refit	1	0.800	1.50	4016.7	920.7	538.7	17774.8	0.849	14,965
Modular FBC refit	1	0.790	1.50	4590.5	889.5	545.6	18118.2	0.833	15,154
Stoker firing refit	Not applicable because existing boiler was designed for #2 oil								
Coal/water slurry	1	0.750	3.00	2413.0	814.8	1149.3	20928.2	0.721	15,963
Coal/oil slurry	1	0.780	3.50	2009.6	724.9	1289.3	20997.5	0.719	6,907
Low Btu gasifier refit	1	0.679	1.75	3596.9	963.4	741.0	19664.1	0.768	16,937
Packaged shell stoker	1	0.760	1.75	3090.1	880.0	661.6	17622.4	0.857	15,123
Packaged shell FBC	1	0.760	1.50	3882.2	890.1	567.1	17618.6	0.857	15,753
Field erected stoker	1	0.800	1.75	5539.7	871.3	628.5	19678.5	0.767	14,366
Field erected FBC	1	0.800	1.50	6068.0	939.9	538.7	20007.0	0.755	14,965
Pulverized coal boiler	1	0.820	1.50	6440.1	971.2	525.6	20550.5	0.735	14,600
Circulating FBC	1	0.810	1.50	7151.6	939.9	532.1	21027.5	0.718	14,780

ARNOLD AFB: AFSC

1. BACKGROUND

Arnold AFB is located near Manchester, Tennessee. The main steam plant (Bldg. 1411) consists of three 72-MBtu/h and one 24-MBtu/h boilers, all of which were designed for medium volatile bituminous coal, but now fire natural gas and distillate (No. 2) oil (secondary fuel). Coal firing was replaced by gas and oil in 1970.

All units are Edgemoor Iron Works waterwall sterling-type boilers, with Edgemoor air preheaters installed on the three larger units. Saturated steam at 200 psig is produced. According to C. H. Guernsey & Co., the large boilers have efficiencies of 76% and the small boilers, 71%. Peak load is reported to be 210 MBtu/h, and the average load is near 70 MBtu/h.

2. HEATING PLANT UNITS

Heating Plant No. 1411

24 MBtu/h; Edgemoor Iron Works (1951)
3 × 72 MBtu/h; Edgemoor Iron Works (1951)

3. IDEAL CAPACITY FACTOR ANALYSIS

Plant No. 1411

Boiler fuel input (MBtu/h)	FY 1978 Ideal capacity factor	FY 1979 Ideal capacity factor
40	0.97	0.98
50	0.91	0.96
70	0.83	0.84
90	0.73	0.72
120	0.58	0.57

4. ENERGY PRICES

FY 1986 Price Data

Electricity = \$13.0/MBtu = 4.44¢/kWh
Distillate oil = \$6.88/MBtu
Natural gas = \$3.81/MBtu

C. H. Guernsey & Co. Survey

Electricity = 4.5¢/kWh
Distillate oil = $3.12/MBtu (possibly incorrect)
Natural gas = $3.97/MBtu

5. COAL CONVERSION PROJECT OUTLOOK

It would probably be most economical to convert one 72-MBtu/h unit back to coal. This corresponds to a fuel input of ~92 MBtu/h. The maximum possible capacity factor based on monthly FY 1978 and FY 1979 data is ~70%. With a 90% equipment availability factor, a realistic capacity factor would be ~60%.

Some coal handling and storage equipment may still be present. Probably only the coal silos are still useful.

Table A.15. Arnold AFS: 1 x 72 MBtu/h, without SO_2 control

Total steam/hot water output	= 72.0 MBtu/h		
Boiler capacity factor	= 0.600		
Number of units for refit	= 1		
Hydrated lime price($/ton)	= 40.00	COAL PROPERTIES	
Ash disposal price ($/ton)	= 10.00		R.O.M. Stoker
Electric price (cents/kWh)	= 4.50	Ash fraction	= 0.100 0.090
Labor rate (k$/year)	= 35.00	Sulfur fraction	= 0.025 0.022
Limestone price ($/ton)	= 20.00	HHV (Btu/lb)	= 12000 12500
FUEL PRICES		FUEL PRICES	
Natural gas price ($/MBtu)	= 3.97	R.O.M. coal ($/MBtu)	= 1.50
#2 Oil price ($/MBtu)	= 0.00	Stoker coal ($/MBtu)	= 1.75
#6 Oil price ($/MBtu)	= 0.00	Coal/H_2O mix ($/MBtu)	= 3.00
OPTIONS		Coal/oil mix ($/MBtu)	= 3.50
Soot blower multiplier	= 0.0		
Tube bank mod multiplier	= 0.0	Primary fuel is 3	
Bottom ash pit multiplier	= 1.0	NATURAL GAS	
SO_2 control multiplier	= 0.0	1=#6 Oil, 2=#2 Oil, 3=NG	
LIMESTONE/LIME			
Inert fraction	= 0.05		
ECONOMIC PARAMETERS			
Project life (year)	= 30		
Discount rate (%/year)	= 10		
Uniform pres worth factor	= 9.427		

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest-ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	3.97	0.0	693.4	1878.0	24239.8	<-- Primary fuel	
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	1	0.800	1.50	3018.9	1079.6	709.6	19885.4	1.219	19,710
Slagging burner refit	1	0.800	1.50	5263.6	1079.6	709.6	22130.2	1.095	19,710
Modular FBC refit	1	0.790	1.50	6057.6	1040.9	718.5	22643.4	1.071	19,959
Stoker firing refit	Not applicable because existing boiler was designed for pulverized coal								
Coal/water slurry	1	0.750	3.00	2732.9	957.4	1513.7	26027.8	0.931	21,024
Coal/oil slurry	1	0.780	3.50	2439.0	848.5	1698.1	26445.6	0.917	9,097
Low Btu gasifier refit	2	0.679	1.75	6175.2	1244.2	975.9	27104.4	0.894	22,307
Packaged shell stoker	2	0.760	1.75	5337.2	1120.9	871.4	24118.6	1.005	19,917
Packaged shell FBC	2	0.760	1.50	6643.1	1133.6	746.9	24370.0	0.995	20,747
Field erected stoker	1	0.800	1.75	7807.4	1017.2	827.8	25200.0	0.962	18,922
Field erected FBC	1	0.800	1.50	8606.1	1102.6	709.6	25689.6	0.944	19,71
Pulverized coal boiler	1	0.820	1.50	9104.1	1135.8	692.3	26337.2	0.920	19,229
Circulating FBC	1	0.810	1.50	10375.0	1097.7	700.8	27328.8	0.887	19,467

HANSCOM AFB: AFSC

1. BACKGROUND

Hanscom AFB is located near Boston in Bedford, Massachusetts. There is a central heating plant (Bldg. 1201) with four boilers, each with a capacity near 50 MBtu/h. All boilers were designed for residual (No. 6) oil combustion and are two-drum, sterling water-tube boilers. The primary fuel is No. 6 oil, with natural gas as the secondary fuel. The steam plant produces 100 psig saturated steam at a yearly average output of 85 to 100 MBtu/h.

2. HEATING PLANT UNITS

Heating Plant No. 1201

3 × 51.3 MBtu/h; Erie City Iron Works (1953)
49.4 MBtu/h; E. Keeler Co. (1961)

3. IDEAL CAPACITY FACTOR ANALYSIS

Plant No. 1201

Boiler fuel input (MBtu/h)	FY 1978 Ideal capacity factor	FY 1979 Ideal capacity factor
60	0.99	0.96
70	0.95	0.92
80	0.91	0.88
90	0.87	0.84
100	0.82	0.80
120	0.71	0.71
150	0.57	0.58

4. ENERGY PRICES

FY 1986 Price Data

Electricity = 6.8¢/kWh
Natural gas = \$2.4–\$3.9/MBtu
Residual oil = \$5.13/MBtu

C. H. Guernsey & Co. Survey

Electricity = 6.07¢/kWh
Natural gas = \$6.2/MBtu (incorrect value)
Residual oil = \$4.67/MBtu

5. OTHER CONSIDERATIONS

In 1980, the planned retirement date for these units was 1985, and the condition of the plant was described as poor. According to the C. H. Guernsey & Co. survey, the same boilers are still intact, but an upgrade of the plant is in progress.

There are discrepancies in the fuel prices and which fuel is used for the boilers. It appears that gas is burned when available and costs \$2.4—\$3.9/MBtu. According to the DEIS data, the gas supply seems to be interruptible and becomes unavailable in the winter months. The price of gas reported in the C. H. Guernsey & Co. survey appears to be inaccurate.

6. COAL CONVERSION PROJECT OUTLOOK

Hanscom AFB has a large fuel-using central heating plant and may be an economical site for coal use. A more accurate price of gas and coal for this base must be determined.

A conceivable conversion project would involve conversion or replacement of one or two units. If coal-firing output capacity of 100 MBtu/h (roughly 125 MBtu/h fuel input) were installed, an overall capacity of about 60% would be expected, assuming a 90% equipment availability. Similarly, for 50-MBtu/h output capacity of coal-based steam generation, an overall capacity factor of ~85% would be expected.

Table A.16. Hanscom AFB: 1 x 50 MBtu/h, without SO_2 control

Total steam/hot water output = 50.0 MBtu/h			
Boiler capacity factor = 0.850			
Number of units for refit = 1			
Hydrated lime price($/ton) = 40.00	COAL PROPERTIES		
Ash disposal price ($/ton) = 10.00		R.O.M.	Stoker
Electric price (cents/kwh) = 6.07	Ash fraction =	0.100	0.090
Labor rate (k$/year) = 35.00	Sulfur fraction =	0.025	0.022
Limestone price ($/ton) = 20.00	HHV (Btu/lb) =	12000	12500
FUEL PRICES	FUEL PRICES		
Natural gas price ($/MBtu) = 0.00	R.O.M. coal ($/MBtu) = 1.50		
#2 Oil price ($/MBtu) = 0.00	Stoker coal ($/MBtu) = 1.75		
#6 Oil price ($/MBtu) = 3.67	Coal/H_2O mix ($/MBtu) = 3.00		
OPTIONS	Coal/oil mix ($/MBtu) = 3.50		
Soot blower multiplier = 0.0			
Tube bank mod multiplier = 1.0	Primary fuel is 1		
Bottom ash pit multiplier = 1.0	#6 FUEL OIL		
SO_2 control multiplier = 0.0	1=#6 Oil, 2=#2 Oil, 3=NG		
LIMESTONE/LIME			
Inert fraction = 0.05			
ECONOMIC PARAMETERS			
Project life (year) = 30			
Discount rate (%/year) = 10			
Uniform pres worth factor = 9.427			

Technology	# of units	Fuel to steam/hot water EFF	Fuel price $/MBtu	Capital Investment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#2 Oil fired boiler		0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler		0.800	3.67	0.0	633.1	1707.9	22069.0	<--- Primary fuel	
Micronized coal refit	1	0.800	1.50	2482.6	1011.7	698.1	18599.9	1.187	19,391
Slagging turner refit	1	0.800	1.50	4298.4	1011.7	698.1	20415.7	1.081	19,391
Modular FBC refit	1	0.790	1.50	4941 [illegible]	969.4	706.9	20744.4	1.064	19,636
Stoker firing refit	Not applicable because existing boiler was designed for #6 oil								
Coal/water slurry	1	0.750	3.00	2514.0	887.5	1489.2	24918.8	0.886	20,683
Coal/oil slurry	1	0.780	3.50	2068.5	789.6	1670.6	25260.5	0.874	8,950
Low Btu gasifier refit	1	0.679	1.75	4034.2	1099.7	960.1	23452.0	0.941	21,945
Packaged shell stoker	1	0.760	1.75	3434.5	954.4	857.3	20513.2	1.076	19,595
Packaged shell FBC	1	0.760	1.50	4376.8	970.2	734.8	20449.9	1.079	20,411
Field erected stoker	1	0.800	1.75	6247.5	941.8	814.4	22803.4	0.968	18,615
Field erected FBC	1	0.800	1.50	6858.9	1023.6	698.1	23088.7	0.956	19,391
Pulverized coal boiler	1	0.820	1.50	7271.5	1052.9	681.0	23617.2	0.934	18,918
Circulating FBC	1	0.810	1.50	8147.7	1033.3	689.4	24387.7	0.905	19,151

KEESLER AFB: ATC

1. BACKGROUND

Keesler AFB is located in Biloxi, Mississippi. Two steam plants could be examined for coal use, one of which serves a hospital. According to the C. H. Guernsey & Co. survey, each of these steam plants has an average fuel consumption rate of 34 MBtu/h (300,000 MBtu/year). According to the DEIS information for FY 1986, significantly less fuel is actually consumed by these boiler plants. All boilers were apparently designed for distillate oil firing.

2. HEATING PLANT UNITS

Heating plant No. 4101

3 × 17 MBtu/h; Nebraska Boiler water-tube units (1984)

Hospital boiler plant

3 × 17 MBtu/h; Keeler water-tube units (1941)
2 × 17 MBtu/h; Superior Iron Works fire-tube boilers (1978)

3. IDEAL CAPACITY FACTOR ANALYSIS

No data were available.

4. ENERGY PRICES

FY 1986 Price Data

Electricity = $14.0/MBtu = 4.1¢/kWh
Distillate oil = none purchased
Natural gas = $3.60/MBtu

C. H. Guernsey & Co. Survey

Electricity = 4.5¢/kWh
Distillate oil = $5.43/MBtu
Natural gas = $3.63/MBtu

5. COAL CONVERSION PROJECT OUTLOOK

It appears that the fuel use reported by the C. H. Guernsey & Co. survey is greater than the actual fuel consumption. Because this is the only load information available to date, it will be used for a preliminary analysis.

Capacity factor values can only be presumed. If a project involved replacement or refit of a single 17 MBtu/h unit, the expected overall load factor would be about 83%. For a project involving two of these units, an overall load factor of 65% might be obtainable.

Table A.17. Keesler AFB: 1 x 17 MBtu/h, without SO_2 control

Total steam/hot water output	= 17.0 MBtu/h		
Boiler capacity factor	= 0.830		
Number of units for refit	= 1		
Hydrated lime price($/ton)	= 40.00	COAL PROPERTIES	
Ash disposal price ($/ton)	= 10.00		R.O.M. Stoker
Electric price (cents/kwh)	= 4.50	Ash fraction	= 0.100 0.090
Labor rate (k$/year)	= 35.00	Sulfur fraction	= 0.025 0.022
Limestone price ($/ton)	= 20.00	HHV (Btu/lb)	= 12000 12500
FUEL PRICES		FUEL PRICES	
Natural gas price ($/MBtu)	= 3.60	R.O.M. coal ($/MBtu)	= 1.50
#2 Oil price ($/MBtu)	= 0.00	Stoker coal ($/MBtu)	= 1.75
#6 Oil price ($/MBtu)	= 0.00	Coal/H_2O mix ($/MBtu)	= 3.00
OPTIONS		Coal/oil mix ($/MBtu)	= 3.50
Scot blower multiplier	= 1.0		
Tube bank mod multiplier	= 1.0	Primary fuel is 3	
Bottom ash pit multiplier	= 1.0	NATURAL GAS	
SO_2 control multiplier	= 0.0	1=#6 Oil, 2=#2 Oil, 3=NG	
LIMESTONE/LIME			
Inert fraction	= 0.05		
ECONOMIC PARAMETERS			
Project life (year)	= 30		
Discount rate (%/year)	= 10		
Uniform pres worth factor	= 9.427		

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest-ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	3.60	0.0	434.0	556.2	9334.3	<-- Primary fuel	
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	1	0.800	1.50	1520.5	707.1	231.8	10370.7	0.900	6,438
Slagging burner refit	1	0.800	1.50	2497.0	707.1	231.8	11347.3	0.823	6,438
Modular FBC refit	1	0.790	1.50	2843.2	687.7	234.7	11538.5	0.809	6,519
Stoker firing refit	Not applicable because existing boiler was designed								
Coal/water slurry	1	0.750	3.00	1488.7	627.2		062.1	0.774	6,867
Coal/oil slurry	1	0.780	3.50	1227.9	562.4	554.6	11757.6	0.794	2,971
Low Btu gasifier refit	1	0.679	1.75	2185.7	708.9	318.8	11873.5	0.786	7,286
Packaged shell stoker	1	0.760	1.75	1956.4	683.8	284.6	11085.9	0.842	6,505
Packaged shell FBC	1	0.760	1.50	2309.5	688.0	244.0	11094.6	0.841	6,777
Field erected stoker	1	0.800	1.75	3279.1	679.7	270.4	12236.0	0.763	6,180
Field erected FBC	1	0.800	1.50	3554.7	724.5	231.8	12569.3	0.743	6,438
Pulverized coal boiler	1	0.820	1.50	3788.8	753.5	226.1	13023.7	0.717	6,281
Circulating FBC	1	0.810	1.50	4050.9	722.6	228.9	13020.3	0.717	6,358

LOWRY AFB: ATC

1. BACKGROUND

Lowry AFB is located near Denver, Colorado, in an area with strict environmental regulations. The boiler plant uses a relatively small amount of fuel, and the chances for an economical use of coal are minimal. All boilers were originally designed to burn subbituminous stoker coal but were subsequently modified for gas and distillate oil firing. The boilers are of four-drum sterling, water-tube design.

2. HEATING PLANT UNITS

Heating Plant No. 361

80.6 MBtu/h; Wickes (1940)
75.6 MBtu/h; Wickes (1941)
2 × 37.8 MBtu/h; Wickes (1940)

3. IDEAL CAPACITY FACTOR ANALYSIS

No data were available.

4. ENERGY PRICES

FY 1986 Price Data

Electricity = \$14.5/MBtu = 5.0¢/kWh
Distillate oil = \$7.44/MBtu
Natural gas = \$3.23/MBtu

C. H. Guernsey & Co. Survey

Electricity = 4.3¢/kWh
Distillate oil = \$6.81/MBtu
Natural gas = \$3.42/MBtu

5. COAL CONVERSION PROJECT OUTLOOK

The fuel use for this boiler plant appears to be in the range of 22.7 to 30.7 MBtu/h. The capacity factor can only be estimated based on analysis of other similar boiler plants. If a project involved conversion or replacement of a 37.8-MBtu/h unit, an overall capacity factor near 50% might be attained.

Table A.18. Lowry AFB: 1 x 38 MBtu/h, without SO_2 control

Total steam/hot water output = 38.0 MBtu/h
Boiler capacity factor = 0.500
Number of units for refit = 1
Hydrated lime price($/ton) = 40.00
Ash disposal price ($/ton) = 10.00
Electric price (cents/kWh) = 4.30
Labor rate (k$/year) = 35.00
Limestone price ($/ton) = 20.00

FUEL PRICES

Natural gas price ($/MBtu) = 3.42
#2 Oil price ($/MBtu) = 0.00
#6 Oil price ($/MBtu) = 0.00

OPTIONS

Soot blower multiplier = 0.0
Tube bank mod multiplier = 0.0
Bottom ash pit multiplier = 1.0
SO_2 control multiplier = 0.0

LIMESTONE/LIME

Inert fraction = 0.05

ECONOMIC PARAMETERS

Project life (year) = 30
Discount rate (%/year) = 10
Uniform pres worth factor = 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction	0.100	0.090
Sulfur fraction	0.025	0.022
HHV (Btu/lb)	12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu) = 1.50
Stoker coal ($/MBtu) = 1.75
Coal/H_2O mix ($/MBtu) = 3.00
Coal/oil mix ($/MBtu) = 3.50

Primary fuel is 3
NATURAL GAS
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Investment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	3.42	0.0	552.2	711.5	11913.1	<-- Primary fuel	
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	1	0.800	1.50	2148.7	870.9	312.1	13300.9	0.896	8,669
Slagging burner refit	1	0.800	1.50	3697.8	870.9	312.1	14850.1	0.802	8,669
Modular FBC refit	1	0.790	1.50	4247.0	847.5	316.0	15215.1	0.783	8,778
Stoker firing refit	1	0.760	1.75	2552.2	842.4	383.3	14106.7	0.844	8,760
Coal/water slurry	1	0.750	3.00	1915.9	777.2	665.8	15518.3	0.768	9,247
Coal/oil slurry	1	0.780	3.50	1692.0	693.1	746.8	15266.3	0.780	4,001
Low Btu gasifier refit	1	0.679	1.75	3443.1	889.8	429.2	15877.6	0.750	9,811
Packaged shell stoker	1	0.760	1.75	2968.4	842.4	383.3	14522.9	0.820	8,760
Packaged shell FBC	1	0.760	1.50	3709.0	847.8	328.5	14797.9	0.805	9,125
Field erected stoker	1	0.800	1.75	5291.4	836.2	364.1	16606.3	0.717	8,322
Field erected FBC	1	0.800	1.50	5791.0	896.6	312.1	17185.3	0.693	8,669
Pulverized coal boiler	1	0.820	1.50	6148.7	929.4	304.5	17780.6	0.670	8,457
Circulating FBC	1	0.810	1.50	6804.7	887.6	308.2	18077.4	0.659	8,562

MAXWELL AFB: ATC

1. BACKGROUND

Maxwell AFB is located just outside of Montgomery, Alabama. The base has one major heating plant (Bldg. 1410) that consists of five boilers. Natural gas is the primary fuel, and No. 5 fuel oil (146,000 MBtu/gal) is the backup fuel. No boilers were designed for coal burning, and it is assumed they were designed for firing No. 5 oil. Saturated steam at 150 psig is produced. The year-round average steam load was reported to be ~41 and 35 MBtu/h from FY 1978 and FY 1979 data, respectively, and 47 MBtu/h in the recent C. H. Guernsey & Co. survey.

2. HEATING PLANT UNITS

Heating Plant No. 1410

3 × 22 MBtu/h; Combustion Engineering Co. (1954)
22 MBtu/h; Babcock and Wilcox Co. (1956)
22 MBtu/h; E. Keeler Co. (1973)

3. IDEAL CAPACITY FACTOR ANALYSIS

Plant No. 1410

Fuel input (MBtu/h)	FY 1978 Ideal capacity factor	FY 1979 Ideal capacity factor
30	0.97	0.96
40	0.86	0.85
50	0.71	0.71
60	0.61	0.60
70	0.53	0.51

4. ENERGY PRICES

FY 1986 Price Data

Electricity = 5.1¢/kWh, 4.4¢/kWh at end of year
Natural gas = $4.93/MBtu
No. 5 oil = unknown

C. H. Guernsey & Co. Survey

Electricity = 5.42¢/kWh
Natural gas = $3.40/MBtu
No. 5 oil = $5.13/MBtu

5. OTHER CONSIDERATIONS

Number 5 oil is a grade of residual oil that is lighter and usually has less ash and sulfur than No. 6 grade.

6. COAL CONVERSION PROJECT OUTLOOK

A conceivable project would involve refit/replacement of one or two of the existing boilers. However, the attractiveness of a refit project is reduced because of the relatively small boiler capacities and the fact that the boilers were not designed to burn coal. A coal project that refit or replaced two 22-MBtu/h units would have an estimated overall capacity factor of ~58%. If the project involved only one boiler, the estimated overall capacity factor could be as high as 86%.

Table A.19. Maxwell AFB: 1 x 22 MBtu/h, without SO_2 control

Total steam/hot water output = 22.0 MBtu/h
Boiler capacity factor = 0.860
Number of units for refit = 1
Hydrated lime price($/ton) = 40.00
Ash disposal price ($/ton) = 10.00
Electric price (cents/kWh) = 5.42
Labor rate (k$/year) = 35.00
Limestone price ($/ton) = 20.00

FUEL PRICES

Natural gas price ($/MBtu) = 3.40
#2 Oil price ($/MBtu) = 0.00
#6 Oil price ($/MBtu) = 0.00

OPTIONS

Soot blower multiplier = 0.0
Tube bank mod multiplier = 1.0
Bottom ash pit multiplier = 1.0
SO_2 control multiplier = 0.0

LIMESTONE/LIME

Inert fraction = 0.05

ECONOMIC PARAMETERS

Project life (year) = 30
Discount rate (%/year) = 10
Uniform pres worth factor = 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction =	0.100	0.090
Sulfur fraction =	0.025	0.022
HHV (Btu/lb) =	12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu) = 1.50
Stoker coal ($/MBtu) = 1.75
Coal/H_2O mix ($/MBtu) = 3.00
Coal/oil mix ($/MBtu) = 3.50

Primary fuel is 3
NATURAL GAS
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest- ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	3.40	0.0	474.4	704.4	11112.3	<-- Primary fuel	
#2 Oil fired boiler	-	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	1	0.800	1.50	1622.2	769.6	310.8	11807.1	0.941	8,632
Slagging burner refit	1	0.800	1.50	2753.6	769.6	310.8	12938.5	0.859	8,632
Modular FBC refit	1	0.790	1.50	3154.9	745.9	314.7	13153.2	0.845	8,742
Stoker firing refit	Not applicable because existing boiler was designed for #6 oil								
Coal/water slurry	1	0.750	3.00	1600.3	680.8	663.0	14268.1	0.779	9,208
Coal/oil slurry	1	0.780	3.50	1304.3	609.4	743.7	14060.2	0.790	3,984
Low Btu sifier refit	1	0.679	1.75	2524.3	788.3	427.4	13984.8	0.795	9,769
Packaged shell stoker	1	0.760	1.75	2232.4	739.9	381.6	12804.6	0.868	8,723
Packaged shell FBC	1	0.760	1.50	2683.2	746.3	327.1	12801.9	0.868	9,087
Field erected stoker	1	0.800	1.75	3817.5	734.1	362.6	14155.7	0.785	8,287
Field erected FBC	1	0.800	1.50	4151.1	786.3	310.8	14492.8	0.767	8,632
Pulverized coal boiler	1	0.820	1.50	4419.5	815.5	303.2	14965.7	0.743	8,422
Circulating FBC	1	0.810	1.50	4776.1	786.8	306.9	15086.4	0.737	8,526

ANDREWS AFB: MAC

1. BACKGROUND

Andrews AFB is located near Washington, D.C. There are three central steam plants on the base, all of which were upgraded in some manner in 1985. Two of these plants, Bldgs. 1515 and 1732, are connected and are large enough to be considered for coal conversion. Each steam plant consists of water-tube boilers that produce saturated steam at 100 psig.

The boilers at Andrews built before 1965 were designed for bituminous coal. Three units installed in 1965 or later are designed for oil. All the boilers presently burn residual oil (No. 6) as the primary fuel, and there is apparently no secondary fuel. Some coal storage silos and receiving hoppers are still on-site.

2. HEATING PLANT UNITS

Heating Plant No. 1515

2 × 59.8 MBtu/h; Bigelow (1958)
2 × 29.9 MBtu/h; Union Iron Works (1946)
15.9 MBtu/h; Union Iron Works (1946)

Heating Plant No. 1732

2 × 33.5 MBtu/h; Keeler Co. (1961)
33.5 MBtu/h; Keeler Co. (1965)

Heating Plant No. 3409

2 × 16 MBtu/h; Keeler Co. (1971)
3 × 15 MBtu/h; Keeler Co. (1960)

3. IDEAL CAPACITY FACTOR ANALYSIS

Maximum possible load factors as a function of project size are given below. Load information was calculated for the combined load of plant Nos. 1515 and 1732.

Plant Nos. 1515 and 1732 (combined)

Fuel input (MBtu/h)	FY 1985 Ideal capacity factor
30	0.92
50	0.76
70	0.67
90	0.60
120	0.51

4. ENERGY PRICES

FY 1986 Price Data

	Year Average	End of Year
Electricity	= 5.4¢/kWh	
Residual oil	= $3.8/MBtu	$2.6/MBtu
Distillate oil	= $5.9/MBtu	$3.3/MBtu

C. H. Guernsey & Co. Survey

Electricity = 5.0¢/kWh
Residual oil = $4.67/MBtu
Distillate oil = $5.56/MBtu

5. OTHER CONSIDERATIONS

Andrews apparently uses a lot of electricity: 100,235 MWh in FY 1986, an average of ~11.4 MW. Residual oil use in FY 1986 was about 568,000 MBtu, an average of ~65 MBtu/h. The highest monthly steam load is ~150 MBtu/h.

A previous study by Roy F. Weston examined connecting boiler plant No. 3409 to the other plants and subsequently building a single coal-fired plant at a cost of $75 million. Andrews has also been the subject of a coal/oil mixture firing study.

6. COAL CONVERSION PROJECT OUTLOOK

Because load factors are low, only conversion of one 60-MBtu/h boiler would probably be considered. The overall load factor for this size project is expected to be about 58%, assuming a 90% equipment availability and the plants are interconnected. If a 30-MBtu/h unit were considered, the load factor might be ~75%.

Table A.20. Andrews AFB (Bldgs. 1515 & 1732): 1 x 33.5 MBtu/h, without SO_2 control

Total steam/hot water output = 33.5 MBtu/h
Boiler capacity factor = 0.750
Number of units for refit = 1
Hydrated lime price($/ton) = 40.00
Ash disposal price ($/ton) = 10.00
Electric price (cents/kWh) = 5.00
Labor rate (k$/year) = 35.00
Limestone price ($/ton) = 20.00

FUEL PRICES

Natural gas price ($/MBtu) = 0.00
#2 Oil price ($/MBtu) = 0.00
#6 Oil price ($/MBtu) = 3.67

OPTIONS

Soot blower multiplier = 0.0
Tube bank mod multiplier = 0.0
Bottom ash pit multiplier = 1.0
SO_2 control multiplier = 0.0

LIMESTONE/LIME

Inert fraction = 0.05

ECONOMIC PARAMETERS

Project life (year) = 30
Discount rate (%/year) = 10
Uniform pres worth factor = 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction	= 0.100	0.090
Sulfur fraction	= 0.025	0.022
HHV (Btu/lb)	= 12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu) = 1.50
Stoker coal ($/MBtu) = 1.75
Coal/H_2O mix ($/MBtu) = 3.00
Coal/oil mix ($/MBtu) = 3.50

Primary fuel is 1
#6 FUEL OIL
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest-ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	3.67	0.0	539.6	1009.7	14605.1	<-- Primary fuel	
Micronized coal refit	1	0.800	1.50	2012.3	862.9	412.7	14037.2	1.040	11,463
Slagging burner refit	1	0.800	1.50	3452.8	862.9	412.7	15477.7	0.944	11,463
Modular FBC refit	1	0.790	1.50	3963.6	835.7	417.9	15780.8	0.925	11,608
Stoker firing refit	1	0.760	1.75	2392.7	828.1	506.8	14977.0	0.975	11,584
Coal/water slurry	1	0.750	3.00	1788.5	764.8	880.4	17297.5	0.844	12,228
Coal/oil slurry	1	0.780	3.50	1576.3	682.2	987.6	17317.2	0.843	5,291
Low Btu gasifier refit	1	0.679	1.75	3203.3	894.0	567.6	16981.9	0.860	12,973
Packaged shell stoker	1	0.760	1.75	2777.9	828.1	506.8	15362.2	0.951	11,584
Packaged shell FBC	1	0.760	1.50	3439.8	836.1	434.4	15416.8	0.947	12,067
Field erected stoker	1	0.800	1.75	4905.1	820.9	481.5	17181.9	0.850	11,005
Field erected FBC	1	0.800	1.50	5360.4	882.6	412.7	17570.9	0.831	11,463
Pulverized coal boiler	1	0.820	1.50	5695.3	913.5	402.6	18102.6	0.807	11,184
Circulating FBC	1	0.810	1.50	6267.7	881.1	407.6	18415.9	0.793	11,322

Table A.21. Andrews AFB (Bldgs. 1515 & 1732): 1 × 60 MBtu/h, without SO_2 control

Total steam/hot water output = 60.0 MBtu/h
Boiler capacity factor = 0.580
Number of units for refit = 1
Hydrated lime price($/ton) = 40.00
Ash disposal price ($/ton) = 10.00
Electric price (cents/kWh) = 5.00
Labor rate (k$/year) = 35.00
Limestone price ($/ton) = 20.00

FUEL PRICES

Natural gas price ($/MBtu) = 0.00
#2 Oil price ($/MBtu) = 0.00
#6 Oil price ($/MBtu) = 3.67

OPTIONS

Soot blower multiplier = 0.0
Tube bank mod multiplier = 0.0
Bottom ash pit multiplier = 1.0
SO_2 control multiplier = 0.0

LIMESTONE/LIME

Inert fraction = 0.05

ECONOMIC PARAMETERS

Project life (year) = 30
Discount rate (%/year) = 10
Uniform pres worth factor = 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction	0.100	0.090
Sulfur fraction	0.025	0.022
HHV (Btu/lb)	12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu) = 1.50
Stoker coal ($/MBtu) = 1.75
Coal/H_2O mix ($/MBtu) = 3.00
Coal/oil mix ($/MBtu) = 3.50

Primary fuel is 1
#6 FUEL OIL
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest- ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	3.67	0.0	653.4	1398.5	19342.7	<-- Primary fuel	
Micronized coal refit	1	0.800	1.50	2736.2	1022.6	571.6	17764.9	1.089	15,878
Slagging burner refit	1	0.800	1.50	4754.8	1022.6	571.6	19783.5	0.978	15,878
Modular FBC refit	1	0.790	1.50	5469.4	987.4	578.8	20234.3	0.956	16,078
Stoker firing refit	1	0.760	1.75	3236.6	977.0	702.0	19063.9	1.015	16,045
Coal/water slurry	1	0.750	3.00	2466.8	907.2	1219.4	22513.6	0.859	16,936
Coal/oil slurry	1	0.780	3.50	2194.9	806.2	1367.9	22689.9	0.852	7,328
Low Btu gasifier refit	2	0.679	1.75	5564.8	1177.3	786.2	24074.4	0.803	17,969
Packaged shell stoker	2	0.760	1.75	4850.6	1065.9	702.0	21516.3	0.899	16,045
Packaged shell FBC	2	0.760	1.50	5959.3	1077.0	601.7	21783.9	0.888	16,713
Field erected stoker	1	0.800	1.75	6981.9	966.2	666.9	22376.9	0.864	15,242
Field erected FBC	1	0.800	1.50	7680.8	1045.3	571.6	22923.0	0.844	15,878
Pulverized coal boiler	1	0.820	1.50	8134.2	1077.8	557.6	23551.3	0.821	15,490
Circulating FBC	1	0.810	1.50	9191.2	1040.7	564.5	24324.0	0.795	15,681

CHARLESTON AFB: MAC

1. BACKGROUND

Charleston AFB is located in North Charleston, South Carolina. The amount of fuel used by the central heat plant (Bldg. 431) is relatively small and is shut down 5 to 7 months each year. The boiler plant has four 50-MBtu/h boilers, three of which originally burned bituminous stoker coal. These boilers were converted to residual oil firing in 1971.

2. HEATING PLANT UNITS

Heating Plant No. 431

3 × 50.3 MBtu/h; Combustion Engineering Inc. (1952)
50.3 MBtu/h; E. Keeler Co. (1972)

3. IDEAL CAPACITY FACTOR ANALYSIS

Plant No. 431

Fuel input (MBtu/h)	FY 1978 Ideal capacity factor	FY 1979 Ideal capacity factor	FY 1985 Ideal capacity factor
20	0.55	0.49	0.42
30	0.53	0.47	0.41
40	0.50	0.45	0.38
50	0.47	0.42	0.35
60	0.45	0.40	0.32
70	0.42	0.37	0.29

4. ENERGY PRICES

FY 1986 Price Data

Electricity = 4.5¢/kWh
Distillate oil = $5.48/MBtu
Residual oil = $4.67/MBtu

C. H. Guernsey & Co. Survey

Electricity = 4.8¢/kWh
(no other data available)

5. COAL CONVERSION PROJECT OUTLOOK

Because relatively little fuel is used at this plant and low load factors exist, it is doubtful that coal will be an economical fuel at this base. The steam plant is shut down for 5–7 months of the year, which makes the capacity factor quite low. A project involving installing 50 MBtu/h of coal-fired steam output capacity would have an expected overall capacity factor of 30–40%. Even a 20-MBtu/h boiler would only have a capacity factor of about 45%.

Table A.2[illegible] Charleston AFB 1 x 50 MBtu/h, without SO_2 control

Total steam/hot water output = 50.0 MBtu/h
Boiler capacity factor = 0.350
Number of units for refit = 1
Hydrated lime price ($/ton) = [illegible]
Ash disposal price ($/ton) = [illegible]
Electric price (cents/kWh) = 4.50
Labor rate (k$/year) = 35.00
Limestone price ($/ton) = 20.00

FUEL PRICES

Natural gas price ($/MBtu) 0.00
#2 Oil price ($/MBtu) 0.00
#6 Oil price ($/MBtu) 3.67

OPTIONS

Soot blower multiplier [illegible]
Tube bank mod multiplier [illegible]
Bottom ash pit multipl [illegible]
SO_2 control multiplier [illegible]

LIMESTONE/LIME

Inert fraction 0.05

ECONOMIC PARAMETERS

Project life (year) 30
Discount rate (%/year) 10
Uniform pres worth factor = 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction =	0.100	0.090
Sulfur fraction =	0.025	0.0[illegible]
HHV (Btu/lb) =	1,000	1,500

FUEL PRICES

R.O.M. coal ($/MBtu) 1.50
Stoker coal ($/MBtu) 1.75
Coal/H_2O mix ($/MBtu) 3.00
Coal/oil mix ($/MBtu) = 3.50

Primary fuel is 1
#6 Fuel oil
1 #6 oil, 2 #2 oil, 3 NG

Technology	# of units	Fuel to steam/ hot water Eff	Fuel price $/MBtu	Capital Invest ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler		0.800	0.00	0.0	0.0	0.0	0.0		
#2 Oil fired boiler		0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler		0.800	3.67	0.0	601.3	703.1	12297.9	-	Primary fuel
Micronized coal refit	1	0.800	1.50	2482.6	934.6	287.4	14002.2	0.878	7,984
Slagging burner refit	1	0.800	1.50	4296.4	934.6	287.4	15818.0	0.777	7,984
Modular FBC refit	1	0.790	1.50	4941.7	909.9	291.1	16263.2	0.756	8,085
Stoker firing refit	1	0.760	1.75	2941.7	905.1	353.0	14801.7	0.831	8,068
Coal/water slurry	1	0.750	3.00	2228.6	836.4	613.2	15893.5	0.774	8,517
Coal/oil slurry	1	0.780	3.50	1977.0	745.4	687.9	15488.5	0.794	3,685
Low Btu gasifier refit	1	0.679	1.75	4034.2	964.0	395.3	16848.2	0.730	9,036
Packaged shell stoker	1	0.760	1.75	3434.5	905.1	353.0	15294.5	0.804	8,068
Packaged shell FBC	1	0.760	1.50	4376.8	910.2	302.6	15809.6	0.778	8,405
Field erected stoker	1	0.800	1.75	6247.5	897.9	335.3	17873.1	0.688	7,665
Field erected FBC	1	0.800	1.50	6858.9	964.2	287.4	18657.9	0.659	7,984
Pulverized coal boiler	1	0.820	1.50	7271.5	998.3	280.4	19325.9	0.636	7,790
Circulating FBC	1	0.810	1.50	8147.7	950.2	283.9	19781.7	0.622	7,886

DOVER AFB: MAC

1. BACKGROUND

Dover AFB is located near Dover, Delaware. The four central heating plant boilers in Bldg. 617 are high-temperature, hot-water (414°F, 275 psi) units. All boilers burn No. 6 oil. The three Combustion Engineering units were designed for coal. In CY 1985 the average heat output was reported to be 35.5 MBtu/h; the January 1985 average output was 76.6 MBtu/h.

2. HEATING PLANT UNITS

Heating Plant No. 617

3 × 50 MBtu/h; Combustion Engineering (1953)
50 MBtu/h; IBW Lamont (1972)

3. IDEAL CAPACITY FACTOR ANALYSIS

Plant No. 617

Fuel input (MBtu/h)	FY 1985 Ideal capacity factor
30	0.94
40	0.84
50	0.76
60	0.70
70	0.63
80	0.58

4. ENERGY PRICES

FY 1986 Price Data

Electricity = \$16.5/MBtu = 5.6¢/kWh
Distillate oil = \$5.87/MBtu
Residual oil = \$5.00/MBtu

C. H. Guernsey & Co. Survey

Electricity = 6.6¢/kWh
Residual oil = \$4.67/MBtu

5. OTHER CONSIDERATIONS

Dover was the site for a recent coal/oil mixture demonstration project. Fuel was supplied by Coaliquids, Inc. About $4 million was spent several years ago to alter one boiler and to add peripheral equipment. The altered boiler may be quite ideal for demonstration of coal/water slurry firing or other coal technologies.

6. COAL CONVERSION PROJECT OUTLOOK

Conversion of one or two units may be a possibility, based on the load data. If one 50-MBtu/h unit was converted to coal, the maximum capacity factor would be about 68%. Assuming 65% as a realistic capacity factor and a 90% equipment availability, an overall load factor of about 59% is obtained.

Table A.23. Dover AFB: 1 x 50 MBtu/h, without SO_2 control

Total steam/hot water output = 50.0 MBtu/h
Boiler capacity factor = 0.590
Number of units for refit = 1
Hydrated lime price($/ton) = 40.00
Ash disposal price ($/ton) = 10.00
Electric price (cents/kWh) = 6.60
Labor rate (k$/year) = 35.00
Limestone price ($/ton) = 20.00

FUEL PRICES

Natural gas price ($/MBtu) = 0.00
#2 Oil price ($/MBtu) = 0.00
#6 Oil price ($/MBtu) = 3.67

OPTIONS

Soot blower multiplier = 0.0
Tube bank mod multiplier = 0.0
Bottom ash pit multiplier = 1.0
SO_2 control multiplier = 0.0

LIMESTONE/LIME

Inert fraction = 0.05

ECONOMIC PARAMETERS

Project life (year) = 30
Discount rate (%/year) = 10
Uniform pres worth factor = 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction =	0.100	0.090
Sulfur fraction =	0.025	0.022
HHV (Btu/lb) =	12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu) = 1.50
Stoker coal ($/MBtu) = 1.75
Coal/H_2O mix ($/MBtu) = 3.00
Coal/oil mix ($/MBtu) = 3.50

Primary fuel is 1
#6 FUEL OIL
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest- ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	3.67	0.0	625.4	1185.5	17070.9	<-- Primary fuel	
Micronized coal refit	1	0.800	1.50	2482.6	988.6	484.5	16369.6	1.043	13,459
Slagging burner refit	1	0.800	1.50	4298.4	988.6	484.5	18185.4	0.939	13,459
Modular FBC refit	1	0.790	1.50	4941.7	952.6	490.7	18547.0	0.920	13,630
Stoker firing refit	1	0.760	1.75	2941.7	941.4	595.0	17425.3	0.980	13,601
Coal/water slurry	1	0.750	3.00	2228.6	873.5	1033.7	20207.2	0.845	14,357
Coal/oil slurry	1	0.780	3.50	1977.0	779.2	1159.6	20253.7	0.843	6,212
Low Btu gasifier refit	1	0.679	1.75	4034.2	1069.2	666.4	20396.1	0.837	15,233
Packaged shell stoker	1	0.760	1.75	3434.5	941.4	595.0	17918.1	0.953	13,601
Packaged shell FBC	1	0.760	1.50	4376.8	953.1	510.0	18169.8	0.940	14,168
Field erected stoker	1	0.800	1.75	6247.5	930.0	565.3	20343.4	0.839	12,921
Field erected FBC	1	0.800	1.50	6858.9	1006.8	484.5	20917.5	0.816	13,459
Pulverized coal boiler	1	0.820	1.50	7271.5	1037.1	472.7	21504.3	0.794	13,131
Circulating FBC	1	0.810	1.50	8147.7	1007.4	478.6	22155.6	0.771	13,293

McCHORD AFB: MAC

1. BACKGROUND

McChord AFB is located near Tacoma, Washington. The central boiler plant (Bldg. 734) consists of three boilers that were designed for subbituminous coal but were converted to gas and oil in 1972. The primary fuel is natural gas, with No. 2 oil being the backup fuel.

2. HEATING PLANT UNITS

Heating Plant No. 734

34.4 MBtu/h; Erie City Iron Works (1955)
34.4 MBtu/h; Erie City Iron Works (1939)
17.2 MBtu/h; Erie City Iron Works (1939)

3. IDEAL CAPACITY FACTOR ANALYSIS

Plant No. 734

Steam output (MBtu/h)	FY 1985 Ideal capacity factor
20	0.94
30	0.82
40	0.72
50	0.62
60	0.51

4. ENERGY PRICES

FY 1986 Price Data

Electricity = 1.45¢/kWh
Natural gas = $3.95/MBtu
Distillate oil = $5.93/MBtu

C. H. Guernsey & Co. Survey

Electricity = 1.64¢/kWh
Natural gas = $2.90/MBtu
Distillate oil = $4.33/MBtu

5. COAL CONVERSION PROJECT OUTLOOK

Low steam loads (averaging about 30 MBtu/h) are a drawback to coal utilization. Conversion of a single 34.4-MBtu/h unit may be the most economical option. The average fuel use in CY 1985 was 39 MBtu/h, which corresponds to an average steam load of 30 MBtu/h.

The theoretical maximum capacity factor based on monthly steam data would be about 78% for a 34.4-MBtu/h unit. In actual practice this would be lower. Assuming a 90% equipment availability, an overall capacity factor of about 68% is estimated to be a realistic value.

Table A.24. McChord AFB: 1 x 34 MBtu/h, without SO_2 control

Total steam/hot water output 34.0 MBtu/h
Boiler capacity factor - 0.680
Number of units for refit 1
Hydrated lime price($/ton) - 40.00
Ash disposal price ($/ton) 10.00
Electric price (cents/kWh) 1.64
Labor rate (k$/year) 35.00
Limestone price ($/ton) - 20.00

FUEL PRICES

Natural gas price ($/MBtu) - 2.90
#2 Oil price ($/MBtu) - 0.00
#6 Oil price ($/MBtu) - 0.00

OPTIONS

Soot blower multiplier 0.0
Tube bank mod multiplier - 0.0
Bottom ash pit multiplier 1.0
SO_2 control multiplier - 0.0

LIMESTONE/LIME

Inert fraction 0.05

ECONOMIC PARAMETERS

Project life (year) - 30
Discount rate (%/year) - 10
Uniform pres worth factor - 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction	0.100	0.090
Sulfur fraction	0.025	0.022
HHV (Btu/lb)	12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu) - 1.50
Stoker coal ($/MBtu) - 1.75
Coal/H_2O mix ($/MBtu) - 3.00
Coal/oil mix ($/MBtu) - 3.50

Primary fuel is 3
NATURAL GAS
1-#6 Oil, 2-#2 Oil, 3-NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Investment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	-	0.800	2.90	0.0	521.6	734.2	11837.7	--- Primary fuel	
#2 Oil fired boiler		0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler		0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	1	0.800	1.50	2027.8	824.6	379.7	13361.0	0.885	10,549
Slagging burner refit	1	0.800	1.50	3480.6	824.6	379.7	14833.9	0.798	10,549
Modular FBC refit	1	0.790	1.50	3995.8	805.9	384.6	15218.0	0.778	10,682
Stoker firing refit	1	0.760	1.75	2410.8	802.9	466.4	14375.8	0.823	10,660
Coal/water slurry	1	0.750	3.00	1803.0	739.2	810.1	16408.7	0.721	11,252
Coal/oil slurry	1	0.780	3.50	1589.5	656.8	908.8	16348.1	0.724	4,869
Low Btu gasifier refit	1	0.679	1.75	3230.5	808.9	522.3	15779.4	0.750	11,938
Packaged shell stoker	1	0.760	1.75	2799.5	802.9	466.4	14764.5	0.802	10,660
Packaged shell FBC	1	0.760	1.50	3470.3	806.3	399.7	14839.5	0.798	11,104
Field erected stoker	1	0.800	1.75	4949.0	799.0	443.0	16657.9	0.711	10,127
Field erected FBC	1	0.800	1.50	5409.3	853.1	379.7	17031.0	0.695	10,549
Pulverized coal boiler	1	0.820	1.50	5746.7	887.4	370.5	17604.5	0.672	10,291
Circulating FBC	1	0.810	1.50	6328.5	840.8	375.1	17790.3	0.665	10,418

McGUIRE AFB: MAC

1. BACKGROUND

McGuire AFB is located near Trenton, New Jersey. The main boiler plant at McGuire (Bldg. 2101) used coal until 1970, when all boilers were switched to natural gas and distillate oil (backup fuel). All boilers are water-tube, high-temperature, hot-water units and have Cleaver Brooks electrostatic precipitators in place. Boiler efficiencies are reported to be 76%. Fuel use is about 800,000 MBtu/year, for an average load of 91 MBtu/h. It is doubtful that any coal-handling equipment is repairable.

2. HEATING PLANT UNITS

Heating Plant No. 2101

4 × 50 MBtu/h; Combustion Engineering (1953)
2 × 31.2 MBtu/h; Erie City (1960)

3. IDEAL CAPACITY FACTOR ANALYSIS

Plant No. 2101

Steam output (MBtu/h)	FY 1985 Ideal capacity factor
20	0.95
30	0.81
40	0.73
50	0.68
60	0.62
70	0.57
80	0.51

4. ENERGY PRICES

FY 1986 Price Data

Year Average	End of Year
Electricity = 7.0¢/kWh	Same
Distillate oil = $6.85/MBtu	Same
Natural gas = $3.85/MBtu	$2.70/MBtu

C. H. Guernsey & Co. Survey

Electricity = 7.8¢/kWh
Distillate oil = $5.56/MBtu
Natural gas = $5.40/MBtu (incorrect value)

An inquiry into the gas price revealed that the price fluctuates and the supply is interruptible. The gas supply is only rarely interrupted, and a cost of ~$4.00/MBtu would be representative.

5. OTHER CONSIDERATIONS

Electric use in FY 1986 was 55,000 MWh — an average of 6.3 MW.

6. COAL CONVERSION PROJECT OUTLOOK

A conversion project using coal to generate 50 MBtu/h of steam may be feasible. Assuming 90% equipment availability, an overall capacity factor of ~60% could be expected (based on CY 1985 data).

Table A.25. McGuire AFB 1 x 50 MBtu/h, without SO_2 control

Total steam/hot water output	[illegible] MBtu/h				
Boiler capacity factor	[illegible]				
Number of units for refit	1				
Hydrated lime price ($/ton)	[illegible]	COAL PROPERTIES			
Ash disposal price ($/ton)	[illegible]			R.O.M.	Stoker
Electric price (cents/kWh)	[illegible]		Ash fraction	[illegible]	[illegible]
Labor rate (k$/year)	[illegible]		Sulfur fraction	[illegible]	[illegible]
Limestone price ($/ton)	[illegible]		HHV (Btu/lb)	12000	[illegible]
FUEL PRICES		FUEL PRICES			
Natural gas price ($/MBtu)	[illegible]	R.O.M. coal ($/MBtu)		1.50	
#2 Oil price ($/MBtu)	[illegible]	Stoker coal ($/MBtu)		1.75	
#6 Oil price ($/MBtu)	[illegible]	Coal/H_2O mix ($/MBtu)		3.00	
OPTIONS		Coal/oil mix ($/MBtu)		3.50	
Soot blower multiplier					
Tube bank mod multiplier	[illegible]	Primary fuel is 3			
Bottom ash pit multiplier	[illegible]	NATURAL GAS			
SO_2 control multiplier	[illegible]	1 #6 Oil, 2 #2 Oil, 3 NG			
LIMESTONE LIME					
Inert fraction	[illegible]				
ECONOMIC PARAMETERS					
Project life (years)	[illegible]				
Discount rate (% year)	10				
Uniform pres worth factor	9.427				

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Investment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler		0.600	4.00	0.0	635.1	1314.0	18374.0	- Primary fuel	
#2 Oil fired boiler		0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler		0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	1	0.800	1.50	2432.6	1008.0	492.8	16629.9	1.105	13,688
Slagging burner refit	1	0.80[illegible]	1.50	4298.4	1008.0	492.8	18445.7	0.996	13,688
Modular FBC refit	1	0.79[illegible]	1.50	4941.7	968.1	499.0	18772.0	0.979	13,861
Stoker firing refit	1	0.760	1.75	2941.7	954.9	605.1	17648.1	1.041	13,832
Coal/water slurry	1	0.750	3.00	2228.6	887.1	1051.2	20500.4	0.896	14,600
Coal/oil slurry	1	0.780	3.50	1977.0	792.6	1179.2	20565.7	0.893	6,317
Low Btu gasifier refit	1	0.679	1.75	4034.2	1112.0	677.7	20905.5	0.879	15,491
Packaged shell stoker	1	0.760	1.75	3434.5	954.9	605.1	18140.9	1.013	13,832
Packaged shell FBC	1	0.760	1.50	4376.8	968.7	518.7	18398.0	0.999	14,408
Field erected stoker	1	0.800	1.75	6247.5	941.9	574.9	20545.6	0.894	13,140
Field erected FBC	1	0.800	1.50	6858.9	1027.3	492.8	21141.5	0.869	13,688
Pulverized coal boiler	1	0.820	1.50	7271.5	1051.1	480.7	21711.5	0.846	13,354
Circulating FBC	1	0.810	1.50	8147.7	1027.5	486.7	22422.1	0.819	13,519

Table A.26. McGuire AFB: 1 × 31.2 MBtu/h, without SO_2 control

Total steam/hot water output = 31.2 MBtu/h
Boiler capacity factor = [illegible].700
Number of units for refit = 1
Hydrated lime price($/ton) = 40.00
Ash disposal price ($/ton) = [illegible]
Electric price (cents/kwh) = [illegible].60
Labor rate (k$/year) = [illegible].00
Limestone price ($/ton) = 20.00

FUEL PRICES

Natural gas price ($/MBtu) = 4.00
#2 Oil price ($/MBtu) = 0.00
#6 Oil price ($/MBtu) = 0.00

OPTIONS

Soot blower multiplier = 0.0
Tube bank mod multiplier = 0.0
Bottom ash pit multiplier = 1.0
SO_2 control multiplier = 0.0

LIMESTONE/LIME

Inert fraction = 0.05

ECONOMIC PARAMETERS

Project life (year) = 30
Discount rate (%/year) = 10
Uniform pres worth factor = 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction =	0.100	0.090
Sulfur fraction =	0.025	0.022
HHV (Btu/lb) =	12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu) = 1.50
Stoker coal ($/MBtu) = 1.75
Coal/H_2O mix ($/MBtu) = 3.00
Coal/oil mix ($/MBtu) = 3.50

Primary fuel is 3
NATURAL GAS
1-#6 Oil, 2-#2 Oil, 3 NG

Technology	# of units	Fuel to steam/hot water EFF	Fuel price $/MBtu	Capital Invest-ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	4.00	0.0	540.6	956.6	14113.9	<-- Primary fuel	
#2 Oil fired boiler		0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	-	0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	1	0.800	1.50	1939.6	870.3	358.7	13525.1	1.044	9,965
Slagging burner refit	1	0.800	1.50	3322.2	870.3	358.7	14907.8	0.947	9,965
Modular FBC refit	1	0.790	1.50	3812.6	838.9	363.3	15145.0	0.932	10,091
Stoker firing refit	1	0.760	1.75	2307.5	8[illegible].2	440.5	14277.6	0.989	10,069
Coal/water slurry	1	0.750	3.00	1720.7	766.5	765.3	16160.7	0.873	10,629
Coal/oil slurry	1	0.780	3.50	1514.9	686.5	858.5	16079.1	0.878	4,599
Low Btu gasifier refit	1	0.679	1.75	[illegible]5.9	930.6	493.4	16499.8	0.855	11,277
Packaged shell stoker	1	0.760	1.75	2676.2	829.2	440.5	14646.3	0.964	10,069
Packaged shell FBC	1	0.760	1.50	3297.1	839.3	377.6	14768.4	0.956	10,489
Field erected stoker	1	0.800	1.75	4700.4	820.1	418.5	16376.4	0.862	9,566
Field erected FBC	1	0.800	1.50	5132.4	884.6	358.7	16853.4	0.837	9,965
Pulverized coal boiler	1	0.820	1.50	5455.0	913.2	350.0	17362.9	0.813	9,721
Circulating FBC	1	0.810	1.50	5984.5	889.1	354.3	17705.9	0.797	9,841

SCOTT AFB: MAC

1. BACKGROUND

Scott AFB is located near Belleville, Illinois. There are four steam plants on this base, but only the major one, in Bldg. 45, is of any interest. The capacity of this plant is ~250 MBtu/h (the others are ~20, 31, and 14 MBtu/h) and is composed of four Erie City Iron Works boilers. The boilers in the main steam plant previously burned coal but were converted to No. 6 oil. Currently, the main plant burns natural gas as well.

2. HEATING PLANT UNITS

Heating Plant No. 45

83 MBtu/h; Erie City Iron Works (1955)
40 MBtu/h; Erie City Iron Works (1952)
84 MBtu/h; Erie City Iron Works (1939)
45 MBtu/h; Erie City Iron Works (1939)

3. IDEAL CAPACITY FACTOR ANALYSIS

Plant No. 45

Steam output (MBtu/h)	FY 1985 Ideal capacity factor
20	0.98
30	0.86
40	0.75
50	0.65
60	0.57
70	0.49
80	0.43

4. ENERGY PRICES

FY 1986 Price Data

Year Average	End of Year
Electricity = 4.1¢/kWh	4.9¢/kWh
Residual oil = $5.28/MBtu	Same
Distillate oil = $5.90/MBtu	Same
Natural gas = $3.64/MBtu	$3.80/MBtu

C. H. Guernsey & Co. Survey

No data were available.

5. COAL CONVERSION PROJECT OUTLOOK

A conversion project would likely involve conversion of one boiler. In CY 1985, the average steam use was 34 MBtu/h. Data for FY 1978-79 and the C. H. Guernsey & Co. survey indicate an average fuel use of 39–44 MBtu/h. A realistic overall capacity factor for a 40-MBtu/h coal burning unit would be about 65%. For an 80-MBtu/h unit, the capacity factor would be near 37%.

Table A.27. Scott AFB: 1 x 40 MBtu/h, without SO_2 control

Total steam/hot water output = 40.0 MBtu/h
Boiler capacity factor = 0.650
Number of units for refit = 1
Hydrated lime price($/ton) = 40.00
Ash disposal price ($/ton) = 10.00
Electric price (cents/kWh) = 4.90
Labor rate (k$/year) = 35.00
Limestone price ($/ton) = 20.00

FUEL PRICES
Natural gas price ($/MBtu) = 3.80
#2 Oil price ($/MBtu) = 0.00
#6 Oil price ($/MBtu) = 0.00

OPTIONS
Soot blower multiplier = 0.0
Tube bank mod multiplier = 0.0
Bottom ash pit multiplier = 1.0
SO_2 control multiplier = 0.0

LIMESTONE/LIME
Inert fraction = 0.05

ECONOMIC PARAMETERS
Project life (year) = 30
Discount rate (%/year) = 10
Uniform pres worth factor = 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction =	0.100	0.090
Sulfur fraction =	0.025	0.022
HHV (Btu/lb) =	12000	12500

FUEL PRICES
R.O.M. coal ($/MBtu) = 1.50
Stoker coal ($/MBtu) = 1.75
Coal/H_2O mix ($/MBtu) = 3.00
Coal/oil mix ($/MBtu) = 3.50

Primary fuel is 3
NATURAL GAS
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest-ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	-	0.800	3.80	0.0	569.3	1081.9	15565.3	<-- Primary fuel	
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler		0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	1	0.800	1.50	2207.1	902.8	427.1	14743.8	1.056	11,863
Slagging burner refit	1	0.800	1.50	3802.8	902.8	427.1	16339.6	0.953	11,863
Modular FBC refit	1	0.790	1.50	4368.5	874.6	432.5	16690.4	0.933	12,013
Stoker firing refit	1	0.760	1.75	2620.5	867.0	524.4	15737.4	0.989	11,987
Coal/water slurry	1	0.750	3.00	1970.5	801.6	911.0	18115.5	0.859	12,653
Coal/oil slurry	1	0.780	3.50	1741.7	714.3	1022.0	18109.5	0.860	5,475
Low Btu gasifier refit	1	0.679	1.75	3546.1	939.1	587.4	17935.7	0.868	13,425
Packaged shell stoker	1	0.760	1.75	3050.0	867.0	524.4	16167.0	0.963	11,987
Packaged shell FBC	1	0.760	1.50	3825.0	875.1	449.5	16312.3	0.954	12,487
Field erected stoker	1	0.800	1.75	5457.7	859.1	498.2	18253.4	0.853	11,388
Field erected FBC	1	0.800	1.50	5976.5	924.7	427.1	18719.2	0.832	11,863
Pulverized coal boiler	1	0.820	1.50	6343.9	956.5	416.6	19288.1	0.807	11,573
Circulating FBC	1	0.810	1.50	7036.9	920.8	421.8	19693.6	0.790	11,716

Table A.28. Scott AFB: 1 x 83 MBtu/h, without SO_2 control

Total steam/hot water output = 83.0 MBtu/h
Boiler capacity factor = 0.370
Number of units for refit = 1
Hydrated lime price($/ton) = 40.00
Ash disposal price ($/ton) = 10.00
Electric price (cents/kWh) = 4.90
Labor rate (k$/year) = 35.00
Limestone price ($/ton) = 20.00

FUEL PRICES

Natural gas price ($/MBtu) = 3.80
#2 Oil price ($/MBtu) = 0.00
#6 Oil price ($/MBtu) = 0.00

OPTIONS

Soot blower multiplier = 0.0
Tube bank mod multiplier = 0.0
Bottom ash pit multiplier = 1.0
SO_2 control multiplier = 0.0

LIMESTONE/LIME

Inert fraction = 0.05

ECONOMIC PARAMETERS

Project life (year) = 30
Discount rate (%/year) = 10
Uniform pres worth factor = 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction	0.100	0.090
Sulfur fraction	0.025	0.022
HHV (Btu/lb)	12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu) = 1.50
Stoker coal ($/MBtu) = 1.75
Coal/H_2O mix ($/MBtu) = 3.00
Coal/oil mix ($/MBtu) = 3.50

Primary fuel is 3
NATURAL GAS
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/hot water EFF	Fuel price $/MBtu	Capital Invest-ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	3.80	0.0	721.5	1277.8	18847.9	<--- Primary fuel	
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	1	0.800	1.50	3261.9	1105.3	504.4	18436.8	1.022	14,011
Slagging burner refit	1	0.800	1.50	5700.9	1105.3	504.4	20875.8	0.903	14,011
Modular FBC refit	1	0.790	1.50	6562.9	1069.4	510.8	21459.4	0.878	14,189
Stoker firing refit	1	0.760	1.75	3845.4	1060.4	619.5	19680.9	0.958	14,159
Coal/water slurry	1	0.750	3.00	2962.1	985.9	1076.1	22400.1	0.841	14,946
Coal/oil slurry	1	0.780	3.50	2649.8	875.9	1207.1	22286.2	0.846	6,467
Low Btu gasifier refit	2	0.679	1.75	6700.9	1279.9	693.8	25306.3	0.745	15,857
Packaged shell stoker	2	0.760	1.75	5753.6	1154.7	619.5	22478.0	0.839	14,159
Packaged shell FBC	2	0.760	1.50	7234.7	1164.3	531.0	23215.3	0.812	14,749
Field erected stoker	1	0.800	1.75	8521.8	1048.4	588.5	23952.7	0.787	13,451
Field erected FBC	1	0.800	1.50	9408.2	1134.5	504.4	24858.1	0.758	14,011
Pulverized coal boiler	1	0.820	1.50	9943.8	1168.7	492.1	25600.3	0.736	13,670
Circulating FBC	1	0.810	1.50	11407.9	1119.9	498.2	26661.4	0.707	13,838

GRAND FORKS AFB: SAC

1. BACKGROUND

Grand Forks AFB is located near Grand Forks, North Dakota. The central heating plant (Bldg. 423) produces hot water at 395°F. All boilers in this heating plant were designed for stoker firing (lignite utilization was attempted but failed) but were later converted to burn No. 6 oil. One boiler can use propane as a backup fuel. Boiler efficiency is reported to be in the range of 65 to 76%. No coal handling equipment remains.

Presently, an electric boiler system is supplying steam by a special agreement with the local utility. Apparently the utility will supply electricity for steam generation at a very reduced price (2.15¢/kWh). This arrangement may not continue much longer.

2. HEATING PLANT UNITS

Heating Plant No. 423

2 × 25 MBtu/h; Combustion Engineering (1956)
25 MBtu/h; International Boiler Works (1958)
42 MBtu/h; International Boiler Works (1958)
42 MBtu/h; International Boiler Works (1964)
Electric boilers (output rating is uncertain)

3. IDEAL CAPACITY FACTOR ANALYSIS

Plant No. 423

Steam output (MBtu/h)	FY 1985 Ideal capacity factor
40	0.82
50	0.76
60	0.71
70	0.65
80	0.59
90	0.53

4. ENERGY PRICES

FY 1986 Price Data

Electricity = 4.2¢/kWh
Distillate oil = $5.41/MBtu
Natural gas = $3.64/MBtu

C. H. Guernsey & Co. Survey

Electricity = 2.15¢/kWh ($6.3/MBtu)
Distillate oil = $6.07/MBtu ($0.91/gal)

5. OTHER CONSIDERATIONS

This base is located near sources of lignite; however, new boilers would be required for lignite firing. The low-cost electricity scheme for the electric-system boiler may cease in the near future.

6. COAL CONVERSION PROJECT OUTLOOK

A refit/replacement project for one or two of the boilers may be economically attractive. It is estimated that refit or replacement of a 42-MBtu/h unit for coal firing could result in an overall capacity factor of about 71%.

Table A.29. Grand Forks AFB: 1 x 25 MBtu/h, without SO_2 control

Total steam/hot water output = 25.0 MBtu/h
Boiler capacity factor = 0.860
Number of units for refit = 1
Hydrated lime price($/ton) = 40.00
Ash disposal price ($/ton) = 10.00
Electric price (cents/kWh) = 4.20
Labor rate (k$/year) = 35.00
Limestone price ($/ton) = 20.00

FUEL PRICES

Natural gas price ($/MBtu) = 0.00
#2 Oil price ($/MBtu) = 0.00
#6 Oil price ($/MBtu) = 3.67

OPTIONS

Soot blower multiplier = 0.0
Tube bank mod multiplier = 0.0
Bottom ash pit multiplier = 1.0
SO_2 control multiplier = 0.0

LIMESTONE/LIME

Inert fraction = 0.05

ECONOMIC PARAMETERS

Project life (year) = 30
Discount rate (%/year) = 10
Uniform pres worth factor = 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction =	0.100	0.090
Sulfur fraction =	0.025	0.022
HHV (Btu/lb) =	12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu) = 1.50
Stoker coal ($/MBtu) = 1.75
Coal/H_2O mix ($/MBtu) = 3.00
Coal/oil mix ($/MBtu) = 3.50

Primary fuel is 1
#6 FUEL OIL
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest- ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#2 Oil fired boiler	-	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	3.67	0.0	488.5	864.0	12750.4	<-- Primary fuel	
Micronized coal refit	1	0.800	1.50	1731.1	788.0	353.1	12488.3	1.021	9,809
Slagging burner refit	1	0.800	1.50	2948.5	788.0	353.1	13705.7	0.930	9,809
Modular FBC refit	1	0.790	1.50	3380.3	765.1	357.6	13964.3	0.913	9,934
Stoker firing refit	1	0.760	1.75	2062.9	759.6	433.7	13311.5	0.958	9,913
Coal/water slurry	1	0.750	3.00	1526.9	699.3	753.4	15221.2	0.838	10,463
Coal/oil slurry	1	0.780	3.50	1339.4	624.5	845.1	15193.0	0.839	4,527
Low Btu gasifier refit	1	0.679	1.75	2712.8	799.2	485.7	14825.6	0.860	11,102
Packaged shell stoker	1	0.760	1.75	2384.8	759.6	433.7	13633.4	0.935	9,913
Packaged shell FBC	1	0.760	1.50	2892.2	765.5	371.7	13613.0	0.937	10,326
Field erected stoker	1	0.800	1.75	4118.3	754.2	412.0	15111.5	0.844	9,417
Field erected FBC	1	0.800	1.50	4485.1	807.4	353.1	15425.2	0.827	9,809
Pulverized coal boiler	1	0.820	1.50	4772.2	837.9	344.5	15918.8	0.801	9,570
Circulating FBC	1	0.810	1.50	5185.4	805.1	348.8	16062.9	0.794	9,688

Table A.30. Grand Forks AFB: 1 x 42 MBtu/h, without SO_2 control

Total steam/hot water output	= 42.0 MBtu/h				
Boiler capacity factor	= 0.710				
Number of units for refit	= 1				
Hydrated lime price($/ton)	= 40.00	COAL PROPERTIES			
Ash disposal price ($/ton)	= 10.00			R.O.M.	Stoker
Electric price (cents/kWh)	= 4.20	Ash fraction	=	0.100	0.090
Labor rate (k$/year)	= 35.00	Sulfur fraction	=	0.025	0.022
Limestone price ($/ton)	= 20.00	HHV (Btu/lb)	=	12000	12500
FUEL PRICES		FUEL PRICES			
Natural gas price ($/MBtu)	= 0.00	R.O.M. coal ($/MBtu)	=	1.50	
#2 Oil price ($/MBtu)	= 0.00	Stoker coal ($/MBtu)	=	1.75	
#6 Oil price ($/MBtu)	= 3.67	Coal/H_2O mix ($/MBtu)	=	3.00	
OPTIONS		Coal/oil mix ($/MBtu)	=	3.50	
Soot blower multiplier	= 0.0				
Tube bank mod multiplier	= 0.0	Primary fuel is 1			
Bottom ash pit multiplier	= 1.0	#6 FUEL OIL			
SO_2 control multiplier	= 0.0	1=#6 Oil, 2=#2 Oil, 3=NG			
LIMESTONE/LIME					
Inert fraction	= 0.05				
ECONOMIC PARAMETERS					
Project life (year)	= 30				
Discount rate (%/year)	= 10				
Uniform pres worth factor	= 9.427				

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Investment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	3.67	0.0	575.6	1198.4	16723.2	<-- Primary fuel	
Micronized coal refit	1	0.800	1.50	2264.3	911.9	489.8	15477.8	1.080	13,605
Slagging burner refit	1	0.800	1.50	3905.7	911.9	489.8	17119.2	0.977	13,605
Modular FBC refit	1	0.790	1.50	4487.5	883.7	496.0	17493.5	0.956	13,778
Stoker firing refit	1	0.760	1.75	2687.3	876.0	601.5	16615.1	1.007	13,749
Coal/water slurry	1	0.750	3.00	2024.0	810.3	1044.9	19512.3	0.857	14,512
Coal/oil slurry	1	0.780	3.50	1790.4	720.6	1172.2	19633.3	0.852	6,279
Low Btu gasifier refit	1	0.679	1.[illegible]5	3647.2	942.2	673.7	18879.7	0.886	15,398
Packaged shell stoker	1	0.760	1.75	3129.9	876.0	601.5	17057.7	0.980	13,749
Packaged shell FBC	1	0.760	1.50	3938.9	884.2	515.6	17134.6	0.976	14,321
Field erected stoker	1	0.800	1.75	5620.9	868.3	571.4	19193.2	0.871	13,061
Field erected FBC	1	0.800	1.50	6158.7	934.6	489.8	19586.2	0.854	13,605
Pulverized coal boiler	1	0.820	1.50	6535.6	967.0	477.8	20156.1	0.830	13,274
Circulating FBC	1	0.810	1.50	7265.4	930.1	483.7	20593.3	0.812	13,437

MINOT AFB: SAC

1. BACKGROUND

Minot AFB is located near Minot, North Dakota. The central heating plant in Bldg. 413 is of interest for this study. The base hospital has a heating plant that is far too small to be considered for coal firing.

The central heating plant has six water-tube boilers that burn natural gas or No. 6 oil (for backup) to produce 400°F hot water. Two boilers (42 and 25 MBtu/h) originally burned stoker coal (lignite utilization was attempted but failed) and were later converted to burn gas or oil. The remaining boilers were designed for residual oil. No coal equipment is still present. The average fuel use was ~70 MBtu/h for FY 1978–79, and apparently dropped to about 53 MBtu/h in 1986.

2. HEATING PLANT UNITS

Heating Plant No. 413

2 × 25 MBtu/h; International Boiler Works (1956)
25 MBtu/h; International Boiler Works (1960)
2 × 25 MBtu/h; Combustion Engineering (1957)
42 MBtu/h; Babcock & Wilcox (1963)

3. IDEAL CAPACITY FACTOR ANALYSIS

Plant No. 413

Fuel input (MBtu/h)	FY 1984 Ideal capacity factor	FY 1985 Ideal capacity factor
40	0.79	0.79
50	0.75	0.75
60	0.70	0.70
70	0.67	0.66
80	0.62	0.62
90	0.57	0.58
100	0.52	0.54

4. ENERGY PRICES

FY 1986 Price Data

Electricity = 3.2¢/kWh
Distillate oil = $5.90/MBtu
Natural gas = $3.90/MBtu

C. H. Guernsey & Co. Survey

Electricity = 1.45¢/kWh
Residual oil = $2.53/MBtu (questionable)
Natural gas = $4.18/MBtu

The DEIS data show no No. 6 oil being purchased in FY 1986. The C. H. Guernsey & Co. survey gives No. 6 as the secondary fuel, costing only $0.38/gal.

5. OTHER CONSIDERATIONS

This base is situated near sources of lignite. However, new boilers would be required to burn lignite.

6. COAL CONVERSION PROJECT OUTLOOK

A conversion project would likely involve refit or replacement of the 42-MBtu/h unit coal-designed boiler. The estimated overall load factor for such a project would be ~64%, assuming a 90% equipment availability factor and other small losses in load factor.

Table A.31. Minot AFB: 1 x 42 MBtu/h, without SO_2 control

Total steam/hot water output = 42.0 MBtu/h
Boiler capacity factor = 0.640
Number of units for refit = 1
Hydrated lime price($/ton) = 40.00
Ash disposal price ($/ton) = 10.00
Electric price (cents/kWh) = 3.20
Labor rate (k$/year) = 35.00
Limestone price ($/ton) = 20.00

FUEL PRICES

Natural gas price ($/MBtu) = 4.18
#2 Oil price ($/MBtu) = 0.00
#6 Oil price ($/MBtu) = 0.00

OPTIONS

Soot blower multiplier = 0.0
Tube bank mod multiplier = 0.0
Bottom ash pit multiplier = 1.0
SO_2 control multiplier = 0.0
LIMESTONE/LIME
Inert fraction = 0.05

ECONOMIC PARAMETERS

Project life (year) = 30
Discount rate (%/year) = 10
Uniform pres worth factor = 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction =	0.100	0.090
Sulfur fraction =	0.025	0.022
HHV (Btu/lb) =	12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu) = 1.50
Stoker coal ($/MBtu) = 1.75
Coal/H_2O mix ($/MBtu) = 3.00
Coal/oil mix ($/MBtu) = 3.50

Primary fuel is 3
NATURAL GAS
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest-ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	4.18	0.0	567.1	1230.3	16943.8	<-- Primary fuel	
#2 Oil fired boiler		0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	1	0.800	1.50	2264.3	893.4	441.5	14848.3	1.141	12,264
Slagging burner refit	1	0.800	1.50	3905.7	893.4	441.5	16489.7	1.028	12,264
Modular FBC refit	1	0.790	1.50	4487.5	869.0	447.1	16894.4	1.003	12,419
Stoker firing refit	1	0.760	1.75	2687.3	863.4	542.2	15937.9	1.063	12,393
Coal/water slurry	1	0.750	3.00	2024.0	797.5	941.9	18421.1	0.920	13,082
Coal/oil slurry	1	0.780	3.50	1790.4	708.7	1056.6	18431.5	0.919	5,660
Low Btu gasifier refit	1	0.679	1.75	3647.2	904.8	607.2	17901.0	0.947	13,880
Packaged shell stoker	1	0.760	1.75	3129.9	863.4	542.2	16380.5	1.034	12,393
Packaged shell FBC	1	0.760	1.50	3938.9	869.5	464.7	16516.9	1.026	12,909
Field erected stoker	1	0.800	1.75	5620.9	857.3	515.1	18557.9	0.913	11,773
Field erected FBC	1	0.800	1.50	6158.7	919.9	441.5	18993.1	0.892	12,264
Pulverized coal boiler	1	0.820	1.50	6535.6	953.7	430.7	19586.9	0.865	11,965
Circulating FBC	1	0.810	1.50	7265.4	910.6	436.1	19960.2	0.849	12,113

Table A.32. Minot AFB: 1 x 25 MBtu/h, without SO_2 control

Total steam/hot water output = 25.0 MBtu/h
Boiler capacity factor = 0.750
Number of units for refit = 1
Hydrated lime price($/ton) = 40.00
Ash disposal price ($/ton) = 10.00
Electric price (cents/kwh) = 3.20
Labor rate (k$/year) = 35.00
Limestone price ($/ton) = 20.00

FUEL PRICES

Natural gas price ($/MBtu) = 4.18
#2 Oil price ($/MBtu) = 0.00
#6 Oil price ($/MBtu) = 3.67

OPTIONS

Soot blower multiplier = 0.0
Tube bank mod multiplier = 0.0
Bottom ash pit multiplier = 1.0
SO_2 control multiplier = 0.0

LIMESTONE/LIME

Inert fraction = 0.05

ECONOMIC PARAMETERS

Project life (year) = 30
Discount rate (%/year) = 10
Uniform pres worth factor = 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction	0.100	0.090
Sulfur fraction	0.025	0.022
HHV (Btu/lb)	12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu) = 1.50
Stoker coal ($/MBtu) = 1.75
Coal/H_2O mix ($/MBtu) = 3.00
Coal/oil mix ($/MBtu) = 3.50

Primary fuel is 3
NATURAL GAS
1 #6 Oil, 2 #2 Oil, 3 NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest-ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	-	0.800	4.18	0.0	482.4	858.2	12637.9	<-- Primary fuel	
#2 Oil fired boiler		0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	-	0.800	3.67	0.0	482.4	753.5	11650.8		
Micronized coal refit	1	0.800	1.50	1731.1	774.3	308.0	11933.6	1.059	8,555
Slagging burner refit	1	0.800	1.50	2948.5	774.3	308.0	13151.0	0.961	8,555
Modular FBC refit	1	0.790	1.50	3380.3	754.4	311.9	13432.3	0.941	8,663
Stoker firing refit	1	0.760	1.75	2062.9	750.5	378.2	12703.3	0.995	8,645
Coal/water slurry	1	0.750	3.00	1526.9	690.1	657.0	14225.7	0.888	9,125
Coal/oil slurry	1	0.780	3.50	1339.4	616.0	737.0	14094.1	0.897	3,948
Low Btu gasifier refit	1	0.679	1.75	2712.8	772.8	423.6	13990.6	0.903	9,682
Packaged shell stoker	1	0.760	1.75	2384.8	750.5	378.2	13025.2	0.970	8,645
Packaged shell FBC	1	0.760	1.50	2892.2	754.8	324.2	13063.4	0.967	9,005
Field erected stoker	1	0.800	1.75	4118.3	746.2	359.3	14539.4	0.869	8,213
Field erected FBC	1	0.800	1.50	4485.1	796.7	308.0	14898.7	0.848	8,555
Pulverized coal boiler	1	0.820	1.50	4772.2	828.2	300.5	15411.6	0.820	8,346
Circulating FBC	1	0.810	1.50	5185.4	790.6	304.2	15505.4	0.815	8,449

PEASE AFB: SAC

1. BACKGROUND

Pease AFB is located near Portsmouth, New Hampshire. The steam plant (Bldg. 124) consists of two 110-MBtu/h water-tube units that fire natural gas as the primary fuel and No. 6 oil as the secondary fuel. These boilers are designed for residual fuel oil combustion. Average fuel use was ~68 MBtu/h for FY 1978, and 73 MBtu/h for FY 1979. The peak winter output demand is ~110 MBtu/h.

2. HEATING PLANT UNITS

<u>Heating Plant No. 124</u>

2 × 110 MBtu/h; Combustion Engineering (1955)

3. IDEAL CAPACITY FACTOR ANALYSIS

Plant No. 124

Fuel input (MBtu/h)	FY 1978 Ideal capacity factor	FY 1979 Ideal capacity factor
40	0.90	0.80
50	0.84	0.75
70	0.74	0.67
90	0.66	0.59
110	0.60	0.50

4. ENERGY PRICES

<u>FY 1986 Price Data</u>

Electricity = $15.5/MBtu = 5.3¢/kWh
Distillate oil = $5.91/MBtu
Residual oil = $4.54/MBtu
Natural gas = $3.8/MBtu

<u>C. H. Guernsey & Co. Survey</u>

Electricity = 6.0¢/kWh
Residual oil = $4.67/MBtu
Natural gas = $4.00/MBtu

5. OTHER CONSIDERATIONS

The data available for FY 1978–79 give monthly No. 6 oil use but not monthly gas use. The annual use of gas was reported instead. Some estimation about monthly load had to be made to project capacity factors. Approximately 25% of the boiler fuel used was natural gas.

6. COAL CONVERSION PROJECT OUTLOOK

Replacement/refit of one boiler may be attractive. It is estimated that the overall capacity factor for converting one 110-MBtu/h unit to coal would be roughly 50%. Because of the high output rating of the boilers in respect to the heat demand, a refit project involving one boiler could include considerable derating for coal firing. Based on price data and recent information, natural gas should be considered as the primary fuel.

Table A.33 Pease AFB, 1 x 60 MBtu/h, without SO_2 control

Total steam/hot water output	60.0 MBtu/h				
Boiler capacity factor	0.600				
Number of units for refit	1				
Hydrated lime price($/ton)	40.00	COAL PROPERTIES			
Ash disposal price ($/ton)	10.00			R.O.M.	Stoker
Electric price (cents/kWh)	5.30		Ash fraction	0.100	0.090
Labor rate (k$/year)	35.00		Sulfur fraction	0.025	0.022
Limestone price ($/ton)	20.00		HHV (Btu/lb)	12000	12500
FUEL PRICES		FUEL PRICES			
Natural gas price ($/MBtu)	3.80		R.O.M. coal ($/MBtu)	1.50	
#2 Oil price ($/MBtu)	0.00		Stoker coal ($/MBtu)	1.75	
#6 Oil price ($/MBtu)	0.00		Coal/H_2O mix ($/MBtu)	3.00	
OPTIONS			Coal/oil mix ($/MBtu)	3.50	
Soot blower multiplier	0.0				
Tube bank mod multiplier	1.0	Primary fuel is 3			
Bottom ash pit multiplier	1.0	NATURAL GAS			
SO_2 control multiplier	0.0	1-#6 Oil, 2-#2 Oil, 3 NG			
LIMESTONE/LIME					
Inert fraction	0.05				
ECONOMIC PARAMETERS					
Project life (year)	30				
Discount rate (%/year)	10				
Uniform pres worth factor	9.427				

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest-ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	-	0.800	3.80	0.0	657.0	1498.0	20314.9	<-- Primary fuel	
#2 Oil fired boiler		0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	-	0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	1	0.800	1.50	2736.2	1030.5	591.3	18025.1	1.127	16,425
Slagging burner refit	1	0.800	1.50	4754.8	1030.5	591.3	20043.7	1.014	16,425
Modular FBC refit	1	0.790	1.50	5469.4	993.7	598.8	20481.3	0.992	16,633
Stoker firing refit	Not applicable because existing boiler was designed for #6 oil								
Coal/water slurry	1	0.750	3.00	2785.2	912.6	1261.4	23279.6	0.873	17,520
Coal/oil slurry	1	0.780	3.50	2297.0	811.3	1415.1	23284.7	0.872	7,581
Low Btu gasifier refit	2	0.679	1.75	5564.8	1193.3	813.3	24480.7	0.830	18,589
Packaged shell stoker	2	0.760	1.75	4850.6	1071.3	726.2	21794.8	0.932	16,598
Packaged shell FBC	2	0.760	1.50	5959.3	1083.3	622.4	22038.5	0.922	17,289
Field erected stoker	1	0.800	1.75	6981.9	970.9	689.9	22638.1	0.897	15,768
Field erected FBC	1	0.800	1.50	7680.8	1051.5	591.3	23167.6	0.877	16,425
Pulverized coal boiler	1	0.820	1.50	8134.2	1083.4	576.9	23785.9	0.854	16,024
Circulating FBC	1	0.810	1.50	9191.2	1049.1	584.0	24585.9	0.826	16,222

Table A.34. Pease AFB: 1 × 70 MBtu/h, without SO_2 control

Total steam/hot water output = 70.0 MBtu/h
Boiler capacity factor = 0.560
Number of units for refit = 1
Hydrated lime price($/ton) = 40.00
Ash disposal price ($/ton) = 10.00
Electric price (cents/kWh) = 5.30
Labor rate (k$/year) = 35.00
Limestone price ($/ton) = 20.00

FUEL PRICES

Natural gas price ($/MBtu) = 3.80
#2 Oil price ($/MBtu) = 0.00
#6 Oil price ($/MBtu) = 0.00

OPTIONS

Soot blower multiplier = 0.0
Tube bank mod multiplier = 1.0
Bottom ash pit multiplier = 1.0
SO_2 control multiplier = 0.0

LIMESTONE/LIME

Inert fraction = 0.05

ECONOMIC PARAMETERS

Project life (year) = 30
Discount rate (%/year) = 10
Uniform pres worth factor = 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction =	0.100	0.090
Sulfur fraction =	0.025	0.022
HHV (Btu/lb) =	12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu) = 1.50
Stoker coal ($/MBtu) = 1.75
Coal/H_2O mix ($/MBtu) = 3.00
Coal/oil mix ($/MBtu) = 3.50

Primary fuel is 3
NATURAL GAS
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest-ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	3.80	0.0	692.8	1631.1	21906.8	<--- Primary fuel	
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	1	0.800	1.50	2973.2	1080.3	643.9	19226.9	1.139	17,885
Slagging burner refit	1	0.800	1.50	5181.3	1080.3	643.9	21435.1	1.022	17,885
Modular FBC refit	1	0.790	1.50	5962.5	1040.5	652.0	21917.8	1.000	18,111
Stoker firing refit	Not applicable because existing boiler was designed for #6 oil								
Coal/water slurry	1	0.750	3.00	3039.2	956.6	1373.6	25005.7	0.876	19,077
Coal/oil slurry	1	0.780	3.50	2511.5	849.7	1540.9	25047.5	0.875	8,255
Low Btu gasifier refit	2	0.679	1.75	6076.4	1259.5	885.6	26297.4	0.833	20,241
Packaged shell stoker	2	0.760	1.75	5258.7	1119.6	790.7	23267.2	0.942	18,073
Packaged shell FBC	2	0.760	1.50	6532.1	1132.7	677.7	23598.7	0.928	18,826
Field erected stoker	1	0.800	1.75	7673.4	1015.5	751.2	24327.6	0.900	17,170
Field erected FBC	1	0.800	1.50	8455.9	1101.7	643.9	24910.9	0.879	17,885
Pulverized coal boiler	1	0.820	1.50	8946.7	1133.8	628.2	25556.1	0.857	17,449
Circulating FBC	1	0.810	1.50	10182.1	1098.4	635.9	26531.0	0.826	17,664

Table A.35. Pease AFB: 1 x 80 MBtu/h, without SO_2 control

Total steam/hot water output	80.0 MBtu/h		
Boiler capacity factor	0.510		
Number of units for refit	1		
Hydrated lime price($/ton	40.00	COAL PROPERTIES	
Ash disposal price ($/ton)	10.00		R.O.M. Stoker
Electric price (cents/kwh)	5.70	Ash fraction	0.100 0.090
Labor rate (k$/year)	35.00	Sulfur fraction	0.025 0.022
Limestone price ($/ton)	20.00	HHV (Btu/lb)	12000 12500
FUEL PRICES		FUEL PRICES	
Natural gas price ($/MBtu)	3.80	R.O.M. coal ($/MBtu)	1.50
#2 Oil price ($/MBtu)	0.00	Stoker coal ($/MBtu)	1.75
#6 Oil price ($/MBtu)	0.00	Coal/H_2O mix ($/MBtu)	3.00
OPTIONS		Coal/oil mix ($/MBtu)	3.50
Soot blower multiplier	0.0		
Tube bank mod multiplier	1.0	Primary fuel is 3	
Bottom ash pit multiplier	1.0	NATURAL GAS	
SO_2 control multiplier	0.0	1-#6 Oil, 2-#2 Oil, 3-NG	
LIMESTONE/LIME			
Inert fraction	0.05		
ECONOMIC PARAMETERS			
Project life (year)	30		
Discount rate (%/year)	10		
Uniform pres worth factor	9.427		

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest-ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	3.80	0.0	724.7	1697.7	22835.7	<--- Primary fuel	
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler		0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	1	0.800	1.50	3197.0	1123.2	670.1	20103.0	1.136	18,615
Slagging burner refit	1	0.800	1.50	5584.1	1123.2	670.1	22490.1	1.015	18,615
Modular FBC refit	1	0.790	1.50	6427.9	1081.3	678.6	23018.4	0.992	18,851
Stoker firing refit	Not applicable because existing boiler was designed for #6 oil								
Coal/water slurry	1	0.750	3.00	3279.3	995.2	1429.6	26138.0	0.874	19,856
Coal/oil slurry	1	0.780	3.50	2714.7	883.6	1603.8	26162.9	0.873	8,592
Low Btu gasifier refit	2	0.679	1.75	6560.3	1316.7	921.7	27661.6	0.826	21,067
Packaged shell stoker	2	0.760	1.75	5642.5	1162.1	823.0	24355.8	0.938	18,811
Packaged shell FBC	2	0.760	1.50	7076.3	1175.7	705.4	24809.2	0.920	19,595
Field erected stoker	1	0.800	1.75	8330.5	1054.7	781.8	25643.3	0.891	17,870
Field erected FBC	1	0.800	1.50	9193.3	1145.5	670.1	26308.8	0.868	18,615
Pulverized coal boiler	1	0.820	1.50	9718.9	1177.8	653.8	26984.8	0.846	18,161
Circulating FBC	1	0.810	1.50	11130.6	1140.3	661.9	28119.7	0.812	18,385

PLATTSBURGH AFB: SAC

1. BACKGROUND

Plattsburgh AFB is located near Plattsburgh, New York. The main boiler plant (Bldg. 2658) has six 50-MBtu/h boilers firing the design fuel, No. 6 oil. The boiler plant produces pressurized hot water with temperatures up to ~400°F. Peak load is estimated to be roughly 195 MBtu/h, and the average load is ~95 MBtu/h.

2. HEATING PLANT UNITS

Heating Plant No. 2658

4 × 50 MBtu/h; International Boiler Works (1955)
2 × 50 MBtu/h; Combustion Engineering (1957)

3. IDEAL CAPACITY FACTOR ANALYSIS

Plant No. 2658

Fuel input (MBtu/h)	FY 1978 Ideal capacity factor	FY 1979 Ideal capacity factor	FY 1984 Ideal capacity factor	FY 1985 Ideal capacity factor
40	1.0	0.98	1.0	0.89
50	0.97	0.93	0.95	0.85
70	0.88	0.83	0.92	0.82
90	0.81	0.77	0.83	0.73
120	0.72	0.69	0.73	0.65
150	0.64	0.60	0.64	0.57

4. ENERGY PRICES

FY 1986 Price Data

Year Average	End of Year
Distillate oil = \$5.90/MBtu	Same
Residual oil = \$5.08/MBtu	Same
Electricity = \$17.3/MBtu = 5.91¢/kWh	6.3¢/kWh

C. H. Guernsey & Co. Survey

Electricity = 6.0¢/kWh
Residual oil = \$5.08/MBtu

5. COAL CONVERSION PROJECT OUTLOOK

Based on load data, a refit/replacement project would probably involve one or two boilers. Residual oil was costing ~$5.08/MBtu, but it should be available for a lower cost. The Stock Fund price of No. 6 oil dropped to $0.55/gal in 1988, which is equal to $3.67/MBtu.

A project involving 100 MBtu/h of capacity would have an expected overall load factor near 62%. A 50-MBtu/h project would have a load factor near 79% (based on 90% equipment availability).

Table A.36. Plattsburgh AFB: 1 x 50 MBtu/h, without SO_2 control

Total steam/hot water output = 50.0 MBtu/h
Boiler capacity factor = 0.790
Number of units for refit = 1
Hydrated lime price($/ton) = 40.00
Ash disposal price ($/ton) = 10.00
Electric price (cents/kWh) = [illegible]
Labor rate (k$/year) = 35.00
Limestone price ($/ton) = 20.00

FUEL PRICES

Natural gas price ($/MBtu) = 0.00
#2 Oil price ($/MBtu) = 0.00
#6 Oil price ($/MBtu) = 3.67

OPTIONS

Soot blower multiplier = 0.0
Tube bank mod multiplier = 1.0
Bottom ash pit multiplier = 1.0
SO_2 control multiplier = 0.0

LIMESTONE/LIME

Inert fraction = 0.05

ECONOMIC PARAMETERS

Project life (year) = 30
Discount rate (%/year) = 10
Uniform pres worth factor = 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction =	0.100	0.090
Sulfur fraction =	0.025	0.022
HHV (Btu/lb) =	12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu) = 1.50
Stoker coal ($/MBtu) = 1.75
Coal/H_2O mix ($/MBtu) = 3.00
Coal/oil mix ($/MBtu) = 3.50

Primary fuel is 1
#6 FUEL OIL
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest-ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	3.67	0.0	632.5	1587.4	20926.6	<-- Primary fuel	
Micronized coal refit	1	0.800	1.50	2482.6	1008.7	648.8	18107.3	1.156	18,022
Slagging burner refit	1	0.800	1.50	4298.4	1008.7	648.8	19923.1	1.050	18,022
Modular FBC refit	1	0.790	1.50	4941.7	967.4	657.0	20254.3	1.033	18,250
Stoker firing refit	Not applicable because existing boiler was designed for #6 oil								
Coal/water slurry	1	0.750	3.00	2514.0	885.8	1384.1	23911.7	0.875	19,223
Coal/oil slurry	1	0.780	3.50	2068.5	788.7	1552.7	24140.6	0.867	8,318
Low Btu gasifier refit	1	0.679	1.75	4034.2	1097.6	892.3	22792.6	0.918	20,396
Packaged shell stoker	1	0.760	1.75	3434.5	952.9	796.8	19928.7	1.050	18,212
Packaged shell FBC	1	0.760	1.50	4376.8	968.1	682.9	19940.7	1.049	18,970
Field erected stoker	1	0.800	1.75	6247.5	940.4	756.9	22248.3	0.941	17,301
Field erected FBC	1	0.800	1.50	6858.9	1021.5	648.8	22604.7	0.926	18,022
Pulverized coal boiler	1	0.820	1.50	7271.5	1050.9	633.0	23144.9	0.904	17,582
Circulating FBC	1	0.810	1.50	8147.7	1029.8	640.8	23896.0	0.876	17,799

Table A.37. Plattsburgh AFB: 2 x 50 MBtu/h, without SO_2 control

Total steam/hot water output	= 100.0 MBtu/h
Boiler capacity factor	= 0.620
Number of units for refit	= 2
Hydrated lime price($/ton)	= 40.00
Ash disposal price ($/ton)	= 10.00
Electric price (cents/kWh)	= 6.30
Labor rate (k$/year)	= 35.00
Limestone price ($/ton)	= 20.00
FUEL PRICES	
Natural gas price ($/MBtu)	= 0.00
#2 Oil price ($/MBtu)	= 0.00
#6 Oil price ($/MBtu)	= 3.67
OPTIONS	
Soot blower multiplier	= 0.0
Tube bank mod multiplier	= 1.0
Bottom ash pit multiplier	= 1.0
SO_2 control multiplier	= 0.0
LIMESTONE/LIME	
Inert fraction	= 0.05
ECONOMIC PARAMETERS	
Project life (year)	= 30
Discount rate (%/year)	= 10
Uniform pres worth factor	= 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction	= 0.100	0.090
Sulfur fraction	= 0.025	0.022
HHV (Btu/lb)	= 12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu)	= 1.50
Stoker coal ($/MBtu)	= 1.75
Coal/H_2O mix ($/MBtu)	= 3.00
Coal/oil mix ($/MBtu)	= 3.50

Primary fuel is 1
#6 FUEL OIL
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest- ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	3.67	0.0	812.9	2491.6	31151.1	<-- Primary fuel	
Micronized coal refit	2	0.800	1.50	4592.8	1374.2	1018.4	27147.1	1.147	28,288
Slagging burner refit	2	0.800	1.50	7952.0	1374.2	1018.4	30506.3	1.021	28,288
Modular FBC refit	2	0.790	1.50	9142.1	1306.5	1031.2	31179.6	0.999	28,646
Stoker firing refit	Not applicable because existing boiler was designed for #6 oil								
Coal/water slurry	2	0.750	3.00	4651.0	1195.9	2172.5	36404.7	0.856	30,173
Coal/oil slurry	2	0.780	3.50	3826.8	1067.6	2437.1	36865.5	0.845	13,056
Low Btu gasifier refit	2	0.679	1.75	7463.2	1551.6	1400.6	35293.4	0.883	32,014
Packaged shell stoker	2	0.760	1.75	6353.9	1283.9	1250.6	30246.0	1.030	28,585
Packaged shell FBC	2	0.760	1.50	8097.0	1307.6	1071.9	30528.9	1.020	29,776
Field erected stoker	1	0.800	1.75	9563.5	1165.4	1188.1	31749.5	0.981	27,156
Field erected FBC	1	0.800	1.50	10579.0	1278.4	1018.4	32230.5	0.967	28,288
Pulverized coal boiler	1	0.820	1.50	11168.1	1306.3	993.5	32847.8	0.948	27,598
Circulating FBC	1	0.810	1.50	12926.3	1290.4	1005.8	34572.5	0.901	27,938

WHITEMAN AFB: SAC

1. BACKGROUND

Whiteman AFB is located near Knob Noster, Missouri. The central heating Plant (Bldg. 140) consists of three water-tube boilers designed for residual oil firing. Currently, the primary fuel is natural gas, and No. 6 oil is the backup fuel. The year-round average fuel use was 25 MBtu/h in FY 1978 and 35 MBtu/h in FY 1979.

2. HEATING PLANT UNITS

Heating Plant No. 140

3 × 35.2 MBtu/h; Keeler (1953)

3. IDEAL CAPACITY FACTOR ANALYSIS

No data were available.

4. ENERGY PRICES

FY 1986 Price Data

Electricity = $14.0/MBtu = 4.8¢/kWh
Distillate oil = $5.91/MBtu
Natural gas = $3.00/MBtu

C. H. Guernsey & Co. Survey

No data were available.

5. OTHER CONSIDERATIONS

The survey by C. H. Guernsey & Co. states that this base is very compact, and little room would be available for coal equipment.

6. COAL CONVERSION PROJECT OUTLOOK

The capacity and fuel use of this heating plant indicates that it is rather small for coal consideration. If a coal project involved replacement or refit of one 35.2-MBtu/h unit, a rough value for the overall capacity factor would be 60%.

Table A.38. Whiteman AFB: 1 x 35.2 MBtu/h, without SO_2 control

Total steam/hot water output 35.2 MBtu/h
Boiler capacity factor = 0.600
Number of units for refit = 1
Hydrated lime price($/ton) = 40.00
Ash disposal price ($/ton) = 10.00
Electric price (cents/kWh) = 4.80
Labor rate (k$/year) = 35.00
Limestone price ($/ton) = 20.00

FUEL PRICES

Natural gas price ($/MBtu) = 3.00
#2 Oil price ($/MBtu) = 0.00
#6 Oil price ($/MBtu) = 0.00

OPTIONS

Soot blower multiplier = 0.0
Tube bank mod multiplier = 1.0
Bottom ash pit multiplier = 1.0
SO_2 control multiplier = 0.0

LIMESTONE/LIME

Inert fraction = 0.05

ECONOMIC PARAMETERS

Project life (year) = 30
Discount rate (%/year) = 10
Uniform pres worth factor = 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction	0.100	0.090
Sulfur fraction	0.025	0.022
HHV (Btu/lb)	12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu) = 1.50
Stoker coal ($/MBtu) = 1.75
Coal/H_2O mix ($/MBtu) = 3.00
Coal/oil mix ($/MBtu) = 3.50

Primary fuel is 3
NATURAL GAS
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest- ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	0.00	0.0	0.0	0.0	0.0	0.033	14,955
Natural gas boiler	--	0.800	3.00	0.0	543.6	693.8	11664.8	<--- Primary fuel	
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
Micronized coal refit	1	0.800	1.50	2064.7	863.4	346.9	13473.6	0.866	9,636
Slagging burner refit	1	0.800	1.50	3546.9	863.4	346.9	14955.8	0.780	9,636
Modular FBC refit	1	0.790	1.50	4072.4	838.3	351.3	15286.2	0.763	9,758
Stoker firing refit	Not applicable because existing boiler was designed for #6 oil								
Coal/water slurry	1	0.750	3.00	2068.7	768.0	740.0	16284.4	0.716	10,278
Coal/oil slurry	1	0.780	3.50	1694.8	685.2	830.2	15980.3	0.730	4,447
Low Btu gasifier refit	1	0.679	1.75	3295.3	888.9	477.1	16172.4	0.721	10,905
Packaged shell stoker	1	0.760	1.75	2851.1	832.2	426.0	14711.7	0.793	9,737
Packaged shell FBC	1	0.760	1.50	3542.9	838.6	365.2	14891.1	0.783	10,143
Field erected stoker	1	0.800	1.75	5053.2	825.4	404.7	16649.5	0.701	9,251
Field erected FBC	1	0.800	1.50	5525.4	886.1	346.9	17148.5	0.680	9,636
Pulverized coal boiler	1	0.820	1.50	5869.0	917.9	338.4	17712.0	0.659	9,401
Circulating FBC	1	0.810	1.50	6473.1	880.6	342.6	18004.3	0.648	9,517

WURTSMITH AFB: SAC

1. BACKGROUND

Wurtsmith AFB is located near Oscoda, Michigan. This base has one major heating plant (Bldg. 305) containing four water-tube boilers that originally fired bituminous stoker coal. Hot water is produced at ~400°F and 250 psig. The peak demand is ~90 MBtu/h, and average load is ~37 MBtu/h.

2. HEATING PLANT UNITS

Heating Plant No. 305

2 × 25 MBtu/h; Combustion Engineering (1957)
31.2 MBtu/h; Erie City Iron Works (1959)
31.0 MBtu/h; International Boiler Works (1961)

3. IDEAL CAPACITY FACTOR ANALYSIS

Plant No. 305

Fuel input (MBtu/h)	FY 1978 Ideal capacity factor	FY 1979 Ideal capacity factor	FY 1984 Ideal capacity factor	FY 1985 Ideal capacity factor
20	0.95	0.95	0.92	0.93
30	0.85	0.85	0.84	0.84
40	0.77	0.77	0.76	0.76
50	0.69	0.69	0.70	0.69
60	0.61	0.62	0.62	0.63
70	0.52	0.54	0.54	0.55
80	0.46	0.48	0.47	0.48

4. ENERGY PRICES

FY 1986 Price Data

Electricity = $16.6/MBtu = 5.67¢/kWh
Residual oil = $4.67/MBtu
Distillate oil = $5.91/MBtu
Natural gas = $5.59/MBtu

C. H. Guernsey & Co. Survey

Electricity = 5.26¢/kWh
Residual oil = $4.67/MBtu
Distillate oil = $5.91/MBtu

Residual oil (No. 6) is the primary fuel, and it is unclear whether distillate is the backup fuel or if there is no secondary fuel. Natural gas is not used for boiler firing.

5. COAL CONVERSION PROJECT OUTLOOK

Load considerations point to a project that would replace or convert one or two of the existing boilers. A conversion project involving 31 MBtu/h of output capacity (~39 MBtu/h input fuel) would have a projected maximum capacity factor of ~78%. Assuming 90% equipment availability, an overall capacity factor of ~68% would be realized. If the two larger boilers were converted (62 MBtu/h output capacity), the overall capacity would be about 45%.

Table A.39. Wurtsmith AFB: 1 x 31 MBtu/h, without SO_2 control

Total steam/hot water output = 31.0 MBtu/h
Boiler capacity factor = 0.680
Number of units for refit = 1
Hydrated lime price($/ton) = 40.00
Ash disposal price ($/ton) = 10.00
Electric price (cents/kWh) = 5.26
Labor rate (k$/year) = 35.00
Limestone price ($/ton) = 20.00

FUEL PRICES

Natural gas price ($/MBtu) = 0.00
#2 Oil price ($/MBtu) = 0.00
#6 Oil price ($/MBtu) = 3.67

OPTIONS

Soot blower multiplier = 0.0
Tube bank mod multiplier = 0.0
Bottom ash pit multiplier = 1.0
SO_2 control multiplier = 0.0

LIMESTONE/LIME

Inert fraction = 0.05

ECONOMIC PARAMETERS

Project life (year) = 30
Discount rate (%/year) = 10
Uniform pres worth factor = 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction =	0.100	0.090
Sulfur fraction =	0.025	0.022
HHV (Btu/lb) =	12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu) = 1.50
Stoker coal ($/MBtu) = 1.75
Coal/H_2O mix ($/MBtu) = 3.00
Coal/oil mix ($/MBtu) = 3.50

Primary fuel is 1
#6 FUEL OIL
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest-ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#2 Oil fired boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler	--	0.800	3.67	0.0	525.6	847.1	12940.7	<-- Primary fuel	
Micronized coal refit	1	0.800	1.50	1933.1	840.8	346.2	13123.6	0.986	9,618
Slagging burner refit	1	0.800	1.50	3310.7	840.8	346.2	14501.1	0.892	9,618
Modular FBC refit	1	0.790	1.50	3799.3	815.3	350.6	14790.3	0.875	9,739
Stoker firing refit	1	0.760	1.75	2300.0	808.7	425.2	13932.0	0.929	9,719
Coal/water slurry	1	0.750	3.00	1714.8	746.0	738.6	15710.3	0.824	10,259
Coal/oil slurry	1	0.780	3.50	1509.4	666.3	828.6	15602.1	0.829	4,439
Low Btu gasifier refit	1	0.679	1.75	3064.7	868.5	476.2	15741.3	0.822	10,885
Packaged shell stoker	1	0.760	1.75	2667.2	808.7	425.2	14299.2	0.905	9,719
Packaged shell FBC	1	0.760	1.50	3284.6	815.7	364.5	14409.7	0.898	10,124
Field erected stoker	1	0.800	1.75	4682.3	801.9	403.9	16050.0	0.806	9,233
Field erected FBC	1	0.800	1.50	5112.3	861.0	346.2	16492.4	0.785	9,618
Pulverized coal boiler	1	0.820	1.50	5433.8	891.8	337.8	17024.6	0.760	9,383
Circulating FBC	1	0.810	1.50	5959.6	858.4	342.0	17275.1	0.749	9,499

Table A.40. Wurtsmith AFB: 1 × 25 MBtu/h, without SO_2 control

Total steam/hot water output = 25.0 MBtu/h
Boiler capacity factor = 0.740
Number of units for refit = 1
Hydrated lime price ($/ton) = 40.00
Ash disposal price ($/ton) = 10.00
Electric price (cents/kWh) = 5.26
Labor rate (k$/year) = 35.00
Limestone price ($/ton) = 20.00

FUEL PRICES

Natural gas price ($/MBtu) = 0.00
#2 Oil price ($/MBtu) = 0.00
#6 Oil price ($/MBtu) = 3.67

OPTIONS

Soot blower multiplier = 0.0
Tube bank mod multiplier = 0.0
Bottom ash pit multiplier = 1.0
SO_2 control multiplier = 0.0

LIMESTONE/LIME

Inert fraction = 0.05

ECONOMIC PARAMETERS

Project life (year) = 30
Discount rate (%/year) = 10
Uniform pres worth factor = 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction	0.100	0.090
Sulfur fraction	0.025	0.022
HHV (Btu/lb)	12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu) = 1.50
Stoker coal ($/MBtu) = 1.75
Coal/H_2O mix ($/MBtu) = 3.00
Coal/oil mix ($/MBtu) = 3.50

Primary fuel is 1
#6 FUEL OIL
1-#6 Oil, 2-#2 Oil, 3-NG

Technology	# of units	Fuel to steam/hot water EFF	Fuel price $/MBtu	Capital Investment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	--	0.800	0.00	0.0	0.0	0.0	0.0		
#2 Oil fired boiler	-	0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler		0.800	3.67	0.0	491.3	743.5	11639.8	<- Primary fuel	
Micronized coal refit	1	0.800	1.50	1731.1	791.8	303.9	12059.7	0.965	8,441
Slagging burner refit	1	0.800	1.50	2948.5	791.8	303.9	13277.1	0.877	8,441
Modular FBC refit	1	0.790	1.50	3380.3	768.3	307.7	13523.3	0.861	8,547
Stoker firing refit	1	0.760	1.75	2062.9	762.5	373.2	12768.4	0.912	8,529
Coal/water slurry	1	0.750	3.00	1526.9	702.0	648.2	14255.6	0.817	9,003
Coal/oil slurry	1	0.780	3.50	1339.4	628.0	727.2	14114.6	0.825	3,896
Low Btu gasifier refit	1	0.679	1.75	2712.8	811.1	417.9	14298.3	0.814	9,553
Packaged shell stoker	1	0.760	1.75	2384.8	762.5	373.2	13090.3	0.889	8,529
Packaged shell FBC	1	0.760	1.50	2892.2	768.6	319.9	13152.9	0.885	8,885
Field erected stoker	1	0.800	1.75	4118.3	756.6	354.5	14592.7	0.798	8,103
Field erected FBC	1	0.800	1.50	4485.1	810.5	303.9	14990.3	0.776	8,441
Pulverized coal boiler	1	0.820	1.50	4772.2	840.6	296.5	15490.7	0.751	8,235
Circulating FBC	1	0.810	1.50	5185.4	808.8	300.1	15639.4	0.744	8,336

Table A.41. Wurtsmith AFB: 2 x 25 MBtu/h, without SO_2 control

Total steam/hot water output = 50.0 MBtu/h
Boiler capacity factor = 0.530
Number of units for refit = 2
Hydrated lime price($/ton) = 40.00
Ash disposal price ($/ton) = 10.00
Electric price (cents/kWh) = 5.26
Labor rate (k$/year) = 35.00
Limestone price ($/ton) = 20.00

FUEL PRICES

Natural gas price ($/MBtu) = 0.00
#2 Oil price ($/MBtu) = 0.00
#6 Oil price ($/MBtu) = 3.67

OPTIONS

Soot blower multiplier = 0.0
Tube bank mod multiplier = 0.0
Bottom ash pit multiplier = 1.0
SO_2 control multiplier = 0.0

LIMESTONE/LIME

Inert fraction = 0.05

ECONOMIC PARAMETERS

Project life (year) = 30
Discount rate (%/year) = 10
Uniform pres worth factor = 9.427

COAL PROPERTIES

	R.O.M.	Stoker
Ash fraction =	0.100	0.090
Sulfur fraction =	0.025	0.022
HHV (Btu/lb) =	12000	12500

FUEL PRICES

R.O.M. coal ($/MBtu) = 1.50
Stoker coal ($/MBtu) = 1.75
Coal/H_2O mix ($/MBtu) = 3.00
Coal/oil mix ($/MBtu) = 3.50

Primary fuel is 1
#6 FUEL OIL
1=#6 Oil, 2=#2 Oil, 3=NG

Technology	# of units	Fuel to steam/ hot water EFF	Fuel price $/MBtu	Capital Invest-ment k$	Annual costs O&M k$	Annual costs Fuel k$	Life cycle cost k$	Benefit /cost ratio	Coal use ton/year
Natural gas boiler	-	0.800	0.00	0.0	0.0	0.0	0.0		
#2 Oil fired boiler		0.800	0.00	0.0	0.0	0.0	0.0		
#6 Oil fired boiler		0.800	3.67	0.0	612.8	1064.9	15815.9	--- Primary fuel	
Micronized coal refit	2	0.800	1.50	3202.5	1055.7	435.3	17257.4	0.916	12,091
Slagging burner refit	2	0.800	1.50	5454.7	1055.7	435.3	19509.6	0.811	12,091
Modular FBC refit	2	0.790	1.50	6253.6	1017.6	440.8	20002.0	0.791	12,244
Stoker firing refit	2	0.760	1.75	3816.3	1009.4	534.5	18370.5	0.861	12,218
Coal/water slurry	2	0.750	3.00	2624.7	929.7	928.6	20342.7	0.777	12,897
Coal/oil slurry	2	0.780	3.50	2478.0	833.4	1041.7	20154.0	0.785	5,580
Low Btu gasifier refit	2	0.679	1.75	5018.6	1100.3	598.7	21034.5	0.752	13,683
Packaged shell stoker	1	0.760	1.75	3434.5	923.3	534.5	17177.4	0.921	12,218
Packaged shell FBC	1	0.760	1.50	4376.8	932.1	458.2	17482.4	0.905	12,727
Field erected stoker	1	0.800	1.75	6247.5	914.1	507.8	19651.6	0.805	11,607
Field erected FBC	1	0.800	1.50	6858.9	985.8	435.3	20255.3	0.781	12,091
Pulverized coal boiler	1	0.820	1.50	7271.5	1018.1	424.6	20872.5	0.758	11,796
Circulating FBC	1	0.810	1.50	8147.7	979.7	429.9	21435.8	0.738	11,941

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